SURFACE ENVIRONMENT & MINING
SEAM
USDA FOREST SERVICE PROGRAM

USER GUIDE to VEGETATION

Mining and Reclamation in the West

U.S.D.A. FOREST SERVICE
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INTERMOUNTAIN FOREST AND RANGE
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RESEARCH SUMMARY

The vegetation specialist working on mined land must be aware of potential impacts of mining, as well as reclamation techniques available to him. This guide covers major points of concern to the vegetation specialist involved in planning for reclamation of mined land, including: exploration and baseline data; species selection; plant materials; site preparation; planting methods; cultural treatments; and post-mining management plan and monitoring.

Information is presented in a question/rule/discussion format, and includes supporting graphic material, notes on additional sources of information, a glossary, and an index.

ACKNOWLEDGMENTS

The contents of this guide are based on presentations and discussions during the Surface Environment and Mining (SEAM) sponsored Vegetation Workshop, February 21-23, 1979, Denver, Colorado. Credit is due all attendees and presenters for their input. Those who attended are listed in appendix B. In addition, major contributors are listed under chapter titles as appropriate.

A special note of thanks is extended to Earl F. Aldon, Ardell J. Bjugstad, Paul E. Packer, and Robert Partido, members of the cadre which planned the workshop. The workshop program coordinator was Edwin R. Browning (SEAM) and the technical adviser was Grant Davis (SEAM).

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USER GUIDE TO VEGETATION
MINING AND RECLAMATION IN THE WEST

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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CONTENTS

INTRODUCTION

MINERAL AND NONMINERAL RESOURCES

An adequate, reliable supply of minerals is essential to the economy and security of the United States, since minerals provide the physical basis for almost all activities of U. S. citizens. While imports can satisfy an important part of the country's minerals demands, they make the U.S. vulnerable to the economic and political decisions of foreign countries. Thus, the mineral deposits within the U. S. are a most important source of this nation's supply.

A substantial portion of the domestic minerals supply presently comes from lands managed by the Federal Government. Federal lands contain a majority of the metallic minerals, as well as major resources of coal, oil shale, geothermal steam, uranium, and oil and gas. These same Federal lands, however, also contain valuable nonmineral resources, including timber, forage, water, wildlife, scenic landforms, and wilderness. The Government's holdings of such resources are now among the most significant in the world.

While it is clearly in the national interest to provide for the identification and production of the mineral resources on Federal land, it is also necessary to provide for a sustained high-level output of the various renewable resources on that land. Thus, the demand for mineral development must be balanced against the demand for renewable resources and the land-management agency's responsibility to reasonably protect the environment affected by mineral-related operations.

MINERALS IN THE LAND-MANAGEMENT PLANNING PROCESS

The Forest Service, as one of the agencies responsible for Federal land management, has a relatively sophisticated planning program for the management of nonmineral resources on land under its jurisdiction. Historically, however, the Forest Service's land-management and planning systems have treated minerals as a distinct category outside of the mainstream of the land-management planning process. There are two basic reasons for this separation:

1. The mining and mineral leasing laws have tended to make mineral activity the preferred use on any Federal land open to such activity. The thinking has been that on lands open to mineral activity, mineral development will generally override the designated primary nonmineral uses.

2. Planning for use of the mineral and nonmineral resources is complicated considerably by the difficulties of identifying and estimating the value of mineral resources. Mineral resources can be found only through costly and risky exploration. Therefore, land-management planning has tended to concentrate, at least until a mineral discovery is made, on the surface resource potential of the land.

The long-standing premise that mineral activity is always the most valuable use of a tract of land is increasingly being challenged. Many mineral deposits being discovered today are of lower grade, located at greater depths, and are therefore more expensive to find and mine than the high grade surface deposits formerly developed. Another significant factor is that nonmineral surface resources are now also considered to be scarce, and their value has increased accordingly.

Hence, when all the mineral and nonmineral values are weighed for a particular proposal at a specific location, the value of the mineral resources may be outweighed by the value of the nonmineral resources. The process of weighing values usually occurs in an Environmental Assessment required by the National Environmental Policy Act of 1969 (NEPA)(P.L.91-190), and is basic to determining the proper mix of uses for any given land area.

Given this situation of mineral and nonmineral values on the same tract of Federal land, decisions as to the proper use of a particular tract of land will always involve balancing the values of mineral and nonmineral resources. If this balancing is to be done in a reasonable manner, adequate information and analysis of all values are needed.

BACKGROUND: THE FORMATION AND MISSION OF SEAM

Realizing the complexity of such decisions, in 1973, the Forest Service chartered the Surface Environment and Mining program (SEAM) to coordinate research, development, and application related to land impacts resulting from minerals exploration and development in the West. From 1973 to 1979, SEAM sponsored more than 150 research and development projects. Together, the projects have greatly added to the body of knowledge surrounding the management of land in mineralized areas. (For purposes of this discussion, mineralized areas are defined as those areas that have some potential for mining.)

To get this knowledge to the specialists in the field in a form they could readily use, SEAM brought together researchers and users from industry, Federal agencies, and the academic community to share their practical knowledge and study results in a series of workshops. The information presented at these workshops is organized into five user guides. Each guide focuses on a specific discipline involved in managing surface resources that may be affected by mineral activities and is written for specialists in these disciplines. The guides will also be of use to land managers, land planners, and other specialists since many activities related to minerals-area management demand that a variety of skills be applied to achieve an integrated approach.

In addition to the User Guide to Vegetation, guides have been written for soils, hydrology, engineering, and sociology and economics. Cross-referencing among these guides is provided in the index. A handbook for minerals specialists has also been written. A handbook for land managers will provide a general overview of administrative considerations surrounding mineral commodities commonly explored for and developed on national forest lands administered by the Forest Service. Concurrent with the development of the SEAM user guides, a USDA handbook on visual management related to mining and reclamation, entitled "Mining," is in press as volume 2 of the National Forest Landscape Management Series. A guide for the wildlife specialty is also planned. All guides will be updated periodically to keep them current with research findings.

The purpose of the guides is to help specialists more clearly understand their role in mineral exploration and development activities by outlining some of the major considerations they must address to insure that such activities integrate with land-management plans; that impacts are mitigated to a reasonable degree; and that reclamation meets state-of-the-art performance standards. Perhaps by using these guides as a common starting point, those involved in minerals management can more easily work together toward achieving these common goals: (1) appropriate consideration of minerals values in land-management planning; (2) protection of surface resources during mining activities; and (3) reclamation of surface-mined land to a productive use.

HOW TO USE THIS GUIDE

The chapters of this guide cover topics that concern the vegetation specialist during both land-management planning and any subsequent minerals activity. Within each chapter, major topics will be addressed in this way:

- Considerations: These are the questions the vegetation specialist should ask about each topic.
- Rules: These general statements answer the questions and direct the vegetation specialist toward the type of site-specific information the land manager may need to make decisions. Rules are set in italic type.

• Discussions: The discussions explain the reasoning behind the rules and in some cases give specific examples of how the rules are applied.

• Exceptions: Exceptions to various statements are given where applicable.

• Additional Information: Here the reader will find basic references to further information on the topic discussed.

The aim of this format is to help define the role of the vegetation specialist in minerals management. The guide is not intended to be a "cookbook" on rehabilitation techniques. Rather, it is intended to set up a logical thought process based on a question/answer approach. Such an approach allows for flexibility, eliminates unnecessary data gathering, helps simplify technical decisionmaking, and allows for a systematic documentation of the decisionmaking process. We hope that this organization of material will make the guides equally useful to users in industry, Federal and State agencies, and the academic community.

The role of the Forest Service staff is illustrated in table 1, "Stages of Mineral Exploration and Development Activities," and table 2, "Roles of Forest Service Specialists in Minerals Activities," which follow this introduction. As you will note, the Forest Service vegetation specialist will advise, review, and monitor. For example, although planting takes place during reclamation, the vegetation specialist will review these plans when the operating plan is submitted prior to development and, if necessary, suggest revisions to the plan to improve reclamation potentials. Then, during mining and reclamation, the Forest Service specialist will monitor these activities according to the approved operating plan. In this way, the effects of the development will be managed in a proactive, rather than reactive mode. In other words, rather than reacting to crises, the vegetation specialist will be part of the forest's interdisciplinary (ID) team from the time land-management planning begins. Then, if and when mineral activities occur, the team will have foreseen potential problems and will have determined general rehabilitation objectives in advance.

Both land-management planning, in its broader application, and site-specific operational planning for mineral activities on National Forest System lands require the full range of interdisciplinary efforts so that information on both the mineral and nonmineral values can be presented to the decisionmaker in an integrated manner. The interdisciplinary approach to planning is uniquely suited to giving the best available assessment of the spectrum of opportunities and problems of managing surface resources that may be affected by mineral-related operations and the requirements needed for reasonable protection of nonmineral resources. Soils, vegetation, hydrology, topography, geology, wildlife, climate, and social and economic information are some of the factors that must be considered by the ID team.

Land management and planning must always proceed on the basis of existing information. In the case of mineral resources, this will almost always be difficult because the mineral resources are hidden beneath the surface and information is provided in increments as exploration proceeds. One of the principal goals of Federal land management, therefore, should be to improve such management by obtaining better mineral-resource information and integrating it into the decisionmaking processes.

When using this guide, the reader should keep in mind that, for the most part, the information is concerned with scientific considerations. While other factors, particularly cost and legal constraints, are a crucial part of the planning process, discussion of these aspects is limited here.

One final note: Successful rehabilitation is as much an art as a science. To clarify specific points or to keep up with new developments, readers are urged to contact the researchers who contributed to this guide or their regional reclamation specialists.

Additional Information:

For more information on the mining process, refer to "Anatomy of a Mine," USDA For. Serv. Gen. Tech. Rep. INT-35. 1977. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Table 1. — *Stages of mineral exploration and development activities*[1]

Prospecting	Exploration	Feasibility studies/operating plan
A. Administrative Action No administrative action required; however, some evidence of mineralization or a hunch	A. Administrative Action Permit/Lease Notice of intent from miner (for certain commodities, may also serve as operating plan if there is minimal surface disturbance) Exploration license EA may be necessary See Handbook for Land Managers (in press) for variation within commodities	A. Administrative Action Submission of necessary permits (EA, EIS, etc.) and operating plan—see Handbook for Land Managers (in press) for variation within commodities
B. Activities Literature search Geological inference Evaluation of existing data Research on rights to land/minerals	B. Activities More intensive literature search Access road construction On-site testing and evaluation of data—geological, geochemical, geophysical, drilling, sampling, shaft sinking Seismic activity Acquiring land/mineral rights Rehabilitation of exploration impacts Environmental and socioeconomic studies	B. Activities Feasibility studies Grade and size of deposit Cost of mining and rehabilitation Market Fiscal Technical studies—mine design Environmental and socioeconomic studies (if not done during exploration) Decision to proceed with development Preparation of operating plan including rehabilitation program and end use Ordering of equipment
C. Environmental Impacts Minimal, if any	C. Environmental Impacts Roads Drill holes Drill pads Dozer holes Exploration camps	C. Environmental Impacts Generally none at this stage
D. Tasks for the Vegetation Specialist None at this point	D. Tasks for the Vegetation Specialist Review of plans to reclaim land impacted by exploration Review and assist in vegetation aspects of environmental studies	D. Tasks for the Vegetation Specialist Review adequacy of operating plan for: Reclamation Program— species selection plant materials site preparation planting methods cultural treatments Monitoring/retreatment program for vegetation Vegetation aspects of end use

[1] The various phases have considerable overlap. The material provided for each phase is illustrative, not complete, and considerable variation is found by commodity. The existence of a forest plan is assumed. Tasks (D) are primarily input from a land-management agency's vegetation specialist. For purposes of discussion, the terms reclamation and rehabilitation are used interchangeably, and mining includes oil and gas activities.

Development[2]	Mining/reclamation	Postmining
A. Administrative Action Approval of necessary operating plan	A. Administrative Action No administrative action required. Mining overlaps with development and reclamation overlaps with mining; reclamation of previously mined areas occurs concurrently with new mining as stipulated in operating plan Any changes in operating plan	A. Administrative Action Release of reclamation bond
B. Activities Securing of financing More extensive testing and definition of the mineral Construction of transportation routes and utilities Construction of mine and processing plant (facilities, water supply, etc.) Construction of waste deposits Continued evaluation of data Change mining plan if necessary	B. Activities Extraction of mineral Processing of mineral Depositing wastes Operation of transportation systems Rehabilitation Monitoring for any changes in biological and physical environment Amend mining and rehabilitation plan if necessary	B. Activities Surface owner manages land after bond release Monitoring for any changes in biological and physical environment Management and maintenance for end-use objective
C. Environmental Impacts Mine Processing plant Waste dumps Transportation and access routes Utilities Increased population resulting from construction	C. Environmental Impacts Impacts directly related to operational aspects of mining; impacts are strongly affected by commodity mined and type of operation	C. Environmental Impacts Directly related to management and maintenance activities
D. Tasks for the Vegetation Specialist Monitor vegetation impacts and activities for conformance to operating plan. Advise on plan revisions when necessary	D. Tasks for the Vegetation Specialist Monitor vegetation impacts and activities for conformance to operating plan. Advise on plan revisions when necessary Advise from a vegetation standpoint on release of reclamation bond	D. Tasks for the Vegetation Specialist Monitor any continued impacts on vegetation Manage vegetation for end-use objective

[2] Development is herein defined as the phase which begins after the right to mine has been established.

Table 2.—*Roles of Forest Service specialists in minerals activities*

	Prospecting	Exploration	Feasibility studies/operating plan
Vegetation specialist	None at this point	Review of plans to reclaim land impacted by exploration Review and assist in vegetation aspects of environmental studies	Review adequacy of operating plan for: Reclamation program — species selection plant materials site preparation planting methods cultural treatments Monitoring/retreatment program for vegetation Vegetation aspects of end use
Soils scientist	None at this point	Review of plans to reclaim land impacted by exploration Review and assist in soils aspects of environmental studies Review soils inventory progress in the the mineralized areas; if needed, recommend timely completion or upgrading	Review adequacy of operating plan for: Reclamation Program— soils surveys storage area selection materials handling plans spoils analysis plan spoils treatments spoils surfacing and erosion control Monitoring/retreatment program for soils Soils aspects of end use
Hydrologist	Establish baseline water-quality monitoring as needed according to plan	Review of plans to reclaim land impacted by exploration Review and assist in hydrologic aspects of environmental studies	Review adequacy of operating plan for: Hydrologic considerations— surface water subsurface water snow management roads impoundments mine drainage Hydrologic aspects of end use
Engineer	None at this point	Review of plans to reclaim land impacted by exploration Review and assist in engineering aspects of environmental studies	Review adequacy of operating plan for: Engineering considerations— air pollution transportation facilities surface-mine facilities mine-waste disposal embankments tailings dams and impoundments subsidence Engineering aspects of end use
Economist	Monitor factors which affect supply and demand for minerals Make forecasts of supply and demand Predict probability	Analyze costs and benefits of alternative exploration methods Participate with the sociologist in identification of existing and emerging issues	Provide expertise in environmental analysis process: issue identification decision criteria cost/benefit analysis of alternatives tradeoff and opportunity-cost evaluations Analyze effects of development on: demand for surface resources human behavioral patterns community economics
Sociologist	Identify the basic social/cultural descriptors of the affected communities Note current trends	Assist in structuring public involvement plan for appropriate: issue identification issue analysis mitigation action Identify critical trigger points from a social perspective	Provide expertise in environmental analysis process: decision criteria issue identification Analyze effects of development on the cultural and political community Consider effects of alternative plans on social well-being

Development	Mining/reclamation	Postmining
Monitor vegetation impacts and activities for conformance to operating plan. Advise on plan revisions when necessary	Monitor vegetation impacts and activities for conformance to operating plan. Advise on plan revisions when necessary Advise from a vegetation standpoint on release of reclamation bond	Monitor any continued impacts on vegetation Manage vegetation for end-use objective
Monitor impacts on soils Monitor soils-related activites for conformance to operating plan. Advise on plan revisions when necessary	Monitor soils impacts and activities for conformance to operating plan. Advise on plan revisions when necessary Advise from a soils standpoint on release of reclamation bond	Monitor any continued impacts on soils Manage soils for end-use objective
Monitor impacts on hydrology	Monitor impacts on hydrology and hydrologic aspects of rehabilitation program Have hydrologic input into release of reclamation bond	Monitor any continued impacts on hydrology Manage hydrology for end-use objective
Monitor engineering-related activities for conformance to operating plan Advise on plan revisions when necessary	Advise from an engineering standpoint on release of reclamation bond	Monitor any continued impacts from engineered structures Manage structures for end-use objective
Record costs Monitor economic changes	Record costs Monitor economic changes	Monitor to determine accuracy of predictions for future use
Monitor Record changes Identify areas of individual or group stress relating to mineral activity and make recommendations to mitigate effects	Monitor Record changes	Monitor and record critical changes to establish new baseline situation

Chapter 1
EXPLORATION AND BASELINE DATA

Chapter Organizer: Grant Davis

Major Contributor: Grant Davis

Mineral exploration is the process of identifying and investigating "targets" in order to discover an economic mineral deposit. Exploration begins with regional studies that create little or no disturbance or occupation of the land. In addition to compiling existing geologic and photogeologic information, exploration also involves geologic mapping and geochemical surveys. By the time a regional study has defined specific target areas, only a small portion of the lands originally considered is selected for more intensive study and exploratory work. At this stage, some land disturbance—drilling, for example—may occur.

Should a mineral deposit be found, the area of land involved is subject to more intensive exploratory work in a tighter pattern and is accompanied by more surface disturbance. If the exploratory work locates an ore body, development and mining are confined to an even more localized land area. Thus, a mining company's decision to explore an area for mineral deposits will require the land-management agency's personnel to become involved in a more intense analysis of the site than would normally occur during land-management planning.

How will the vegetation specialist be involved with the mining company during exploration?

The vegetation specialist will advise the land manager on the impacts that exploration may cause to the vegetation, and may or may not work with the mining company in collecting preliminary data on the site.

Discussion:

Impacts on the vegetation might include erodibility and soil toxicity problems or disturbing a critical plant species stand. The vegetation specialist should work closely with the soils scientist in assessing these impacts and advising on their mitigation. In addition, if an exploration permit was required from the mining company, the vegetation specialist should review it from the aspect of the steps planned to revegetate the sites disturbed by exploratory activities.

During exploration, the mining company will drill to determine if the mineral resource is minable. The Forest Service should ask the mining company to provide drilling data and cores collected during exploration. Keep in mind that such information may be proprietary. Any data already gathered at this stage, however, may be helpful if and when the decision to mine is made because it could provide preliminary information on potential problems, such as toxicity or erodibility, that may be encountered later during development and mining. In addition, if exploration leads to the mining company's decision to mine the site, the timespan for collecting data may be short, and thus any data already gathered may be helpful in answering specific questions posed in the Environmental Assessment.

Does the Forest Service have access to a mining company's data?

If a mining company has collected data about a leasable mineral, the company is required to give the Forest Service certain information about such mineral deposits. A prospecting permit may require the company to supply this information. A coal license absolutely requires this information from a mining company. For locatable minerals, any information collected is considered "privileged," and the company that collected it controls access to it.

Discussion:

Because mining companies have complete control of certain information they collect dur-

ing exploration, prior data collection by the Forest Service ID team is essential. The Forest Service should have information about every mine site on its land, whether for a leasable or locatable mineral, because, in either case, it will be the responsibility of the Forest Service to insure that surface conditions are not irrevocably harmed during mining. In addition, a close working relationship between the Forest Service and the mining company, developed early in the mining process, can be beneficial to both parties since their combined effort can produce a more thorough data base.

BASELINE DATA AND THE MINING PLAN

Once exploration is complete and the mining company determines that it will mine the site, an Environmental Assessment may be in order and the formal gathering of baseline data to be included in the mining plan begins. Baseline data measure the conditions existing on the site prior to disturbance, help determine reclamation goals, and provide a basis against which reclamation success can be measured. Based on these comparisons, the mining operator may or may not be released from his bond of liability subsequent to mining and reclamation activities.

At this point, more specific information about the site may be needed to answer specific issues or management concerns identified in the planning process. This information must be scientifically sound and well documented in case it is later challenged. In addition, ID team members should coordinate their efforts so that the data collected do not overlap.

What is the role of the vegetation specialist in the collection of baseline data and approval of the mining plan?

The vegetation specialist will be specifically concerned with data needed to answer questions related to vegetation in the Environmental Assessment. He should require data sufficient to allow him to advise the land manager whether to accept, reject, or modify a company's mining plan, based on how the plan addresses vegetative considerations. All vegetative information collected should be relevant to this objective.

Discussion:

The vegetation specialist should determine what information is appropriate to the concerns that need to be answered, what funds are available for collecting the data, and who will collect it. He should require only the level of data needed to answer specific questions for the land manager or to meet legal requirements. This level of data usually requires on-site studies (fig. 1) and selecting an appropriate vegetation classification system to conduct the on-site studies. Vegetation classification systems vary widely, and generally the vegetation specialist can rely on the system that has been in use in his area.

Vegetative data generally needed include identification of existing vegetation on the site by species composition, its productivity and cover density, and its prior use. Native versus introduced species, threatened and endangered plant species, animals supported by the vegetation, yearly and seasonal variability, and potential pest problems should also be noted.

Productivity measurements are important because the mining plan, or law, may state that the vegetation productivity after mining will be equal to, or greater than, it was prior to mining. Productivity and cover density can be measured using exclosures, plots, or transects. In places where present vegetation does not reflect the true potential or where rehabilitation goals require a change in vegetation types, potential productivity will have to be based on soil types as determined with the help of the soils scientist.

In addition to analyzing productivity of the vegetation on undisturbed soils, an estimate of the productivity of the overburden strata is also important because these materials may become the plant-growth medium after mining. Further analysis of the drilling samples will aid in this evaluation. Past, present, and potential uses of the vegetation are also important considerations and should be noted in the baseline data.

Information on threatened and endangered plant and animal species should be obtained. The vegetation specialist can work with the wildlife specialist or consult State and Federal lists for information on such species. In addition, he should be aware of the characteristic habitats of endangered animal species. This information may indicate that the site to be mined is a typical habitat of a threatened or endangered species even if the animal is not observed during base-

Figure 1. On-site study plots are valuable in testing proposed revegetation techniques. (Decker Coal Mine)

line data collection. If so, the site may have to be returned to the same type of vegetation after mining in order to preserve critical habitat.

A consideration in baseline data collection is that the season in which the data were collected affects productivity measurements, because certain species are dominant at certain times of the year. In addition, any amendments added to the soil may temporarily increase productivity, and thus skew the accuracy of baseline productivity measurements.

To assess potential pest problems, baseline data should note whether there are noxious weeds in the area that might invade the site or whether potential animal pest problems exist.

After analysis of these data, the vegetation specialist should be able to advise the land manager whether to accept, reject, or modify a company's mining plan, based on how the plan addresses vegetation considerations. The vegetation specialist may also be responsible for proposing options to the mining plan either alone or as a member of an ID team. The land manager can request a periodic review of the plan during which changes can be made if (1) the mining processes are unreasonably damaging vegetative resources; or (2) only preliminary baseline data are included in the mining plan.

Who collects baseline vegetative data?

Either the Forest Service or the mining company may collect the baseline data. Responsibility for data collection will be negotiated between the Forest Service and the mining company in each mining situation after the company has made the decision to mine.

Discussion:

When the mining operation will be on Forest Service land, it is the responsibility of the land manager to determine if the mining plan has an adequate baseline data design, and then if the

data are collected according to the plan.

Although it is the responsibility of the Forest Service to insure that baseline data requirements are met by operators on Forest Service land, in certain areas of the country the Forest Service is considering allowing State agencies to enforce their own State requirements on National Forest System lands because these regulations are at least as stringent as Forest Service or Federal requirements. An example is the State of Wyoming. In these situations, the Forest Service will still approve mining plans and will retain authority over Forest Service lands.

In the case of small mine operators, extensive data collection may be economically unfeasible. To aid these operators, Federal assistance can be applied for through the Small Operators Assistance Program, Office of Surface Mining, U. S. Dept. of the Interior. This program was established by the Surface Mining and Reclamation Act of 1977 (P.L. 95-87, 30 U.S.C., Secs. 1201 et seq.).

Who must gather the vegetative information for environmental assessments if they are required?

If the operation is located on national forest lands, the forest supervisor may be required to provide baseline data, in which case the vegetation specialist will probably be involved in data collection.

Discussion:

The Forest Service vegetation specialist may be actively involved in data collection, or involved only in review of the data, depending on who must supply the data. In either case, the same kind of information is needed.

Should baseline data be computerized?

If a large amount of data will be collected or an Environmental Assessment or Environmental Impact Statement is required, computerizing the data may aid in easy retrieval during mining activity and postmining monitoring.

Discussion:

The decision to computerize the data should be made before or in the early stages of the data collection process. If there is going to be a large baseline requirement and an intense monitoring requirement throughout the mining process, the option to computerize the data should be considered.

What other activities are important considerations during baseline studies?

The vegetation specialist should urge those doing baseline studies to watch for archaeological resources as the site is examined. The specialist should also encourage establishment of permanent study plots for use throughout the mining, reclamation and postmining phases.

Discussion:

Although a trained archaeologist will conduct an official paleontological or archaeological survey, all members of the team should aid in locating such objects during field studies.

Study plots will be essential throughout the mining process to determine what reclamation techniques are most successful on the site.

Additional Information:

For more information on baseline studies, refer to "A Systems Approach to Ecological Baseline Studies," U.S. Dept. of the Interior, Biological Services Program, Fish and Wildlife Service, FWS/OBS-78/21. March 1978.

For more information on a vegetation classification system that has been developed for ecosystems in the Southwest, contact the USDA Forest Service, Rocky Mt. For. and Range Exp. Stn., Albuquerque, N.M.

Chapter 2
SPECIES SELECTION

Chapter Organizer: Ray W. Brown

Major Contributors: Ray W. Brown, Kay H. Asay, Neil C. Frischknecht, Richard L. Hodder

Among the first critical tasks in rehabilitating a mine site is the selection of the plant species to be used. The vegetation specialist must be familiar with both legal requirements and the land-management goals affecting revegetation and choose the adapted species accordingly. For example, if the area will be reclaimed for livestock grazing, the adapted species should be palatable to livestock. Correct species selection can be a difficult decision, but it is vital to reclamation success because, once permanently established, vegetation will provide ground cover, reduce or prevent erosion, and eventually will return the site to a usable condition.

Why is proper species selection complex?

The major reason is that not all species are adapted to all sites or uses, and a number of factors affect adaptability. Usually, there are many more species that are only marginally adapted to a given site than are truly adapted.

Discussion:

The vegetation specialist must be able to identify these adapted species because the ability of a species or ecotype to adapt—to complete its entire life cycle and replace itself in succeeding generations—to a specific site is a key to successful land rehabilitation.

Exception: Nurse crops, also called companion crops, may be unadapted to a mine site. These plants are usually annual species that can be planted either before or with the permanent species to temporarily stabilize the site and aid in the establishment of the permanent species. They are useful in certain situations when immediate stability of the land or amelioration of soil characteristics can be more effectively accomplished by including a nurse crop with the permanent planting. While some researchers have had success by planting a harsh site with a nurse crop of a species that will persist several years, other researchers have found that nurse crops are not desirable because they delay or reduce permanent seedling establishment due to their excessive competition. In these cases, researchers have been more successful by initially seeding with primary, adapted species that are capable of plant colonization. (For a further discussion of nurse crops, see chapter 6.)

Can both native and introduced species be considered adapted species?

Both introduced and native species can be successful in revegetating disturbed lands if they are adapted to the site (fig. 2). Although some State laws direct the use of native plants, most researchers agree that the term "adapted" is

Figure 2. Native species will often invade a revegetated mine site.

more appropriate to a discussion of species selection.

Discussion:
When considering introduced species, review Executive Order 11987, "Exotic Organisms." May 24, 1977.

What criteria should be considered in selecting adapted species?

Adaptability is intimately tied to the ability of a plant to complete its entire life cycle and to reproduce itself from year to year over a long period. The plant's growth form, drought resistance or tolerance to stress, mineral nutrition requirements, and reproduction characteristics are all important considerations when selecting an adapted species. Availability of seed and competition among species being planted are also important factors.

Discussion:
Species selection is complex and involves, in addition to consideration of the species itself, a trade off among many interacting factors. These include: Federal, State and local requirements; rehabilitation objectives; nature of the site; time and timing; species compatibility; mechanical limitations on planting; seed and seedling availability; maintenance after planting; and cost.

• **Legal requirements**. Laws concerning rehabilitation standards are changing rapidly. As part of planning, check Federal, State, and local regulations to make sure the species selected fulfill these requirements. State seed laws may also affect the importation of certain seeds.

• **Rehabilitation objectives**. The vegetation specialist must know what functions the plants are to serve. The species selected are heavily dependent on this answer.

For example, if the goal is to provide a wildlife habitat, a variety of grasses, forbs, shrubs, and trees may be desirable in order to provide feed, cover, and nesting for birds and animals. If other end uses, such as for crops, rangeland forage, natural beauty, or recreation are the goals, different types of species may be more appropriate.

> Exception: Regarding wildlife habitat, some land managers prefer to manage a site for one animal species, rather than to try to provide cover for a variety of animals. Obviously, this simplifies the job of determining required wildlife habitat.

Additional Information:
For more information on wildlife habitat requirements, refer to:

"Run Wild," Wildlife Research Program, USDA Forest Service, Rocky Mt. For. and Range Exp. Stn., Albuquerque, N.M.

"Rehabilitation of Western Wildlife Habitat: A Review," prepared by the staff of the Institute for Land Rehabilitation, Utah State University, Logan, Utah. Edited by Western Energy and Land-Use Team, Phillip L. Dittberner, Project Officer. Ft. Collins, Colo. FWS/OBS-78/86. December 1978.

• **Nature of the site**. Without exception, the permanent species selected must be adapted to the site. Specifically:

1. Plants must be adapted to the **soil**. To determine soil characteristics, tests are necessary to establish pH, fertility, texture, depth, permeability, presence of toxic materials, and water-retention capacity.

It has been noted that in the vast majority of cases, topsoil provides the most suitable growing medium for plants because it has the fertility and physical conditions needed for plant growth. In addition, more species are adapted to topsoil than to subsurface material.

> Exception: In a few cases, subsoil may provide better plant productivity than topsoil. Examples of such subsoils are carbonaceous shales or clay loams, as compared to silty clays. These soils, however, often are infertile and must be fertilized in order to provide an adequate growth medium. The characteristics of subsoils can be artificially altered to provide the fundamental requirements of plants by fertilizing, liming, mulching, adding organic matter, and other treatments.

Even if topsoil provides an excellent growing medium for one type of species—for example, grasses—before mining, it may not be adequate as a growing medium for a postmining use by another species—for example, trees—because of

differences in rooting depths, nutrient needs, etc.

2. Plants must be adapted to local **precipitation**, both amounts and seasonal distribution. For example, a number of shrub species are particularly adapted to droughty and saline sites because of the structural and physiological adaptation of their roots and foliage.

> **Exception:** Some species that would not ordinarily be selected because they are difficult to establish may be included if supplemental irrigation is planned and they are adapted to the site. It should be kept in mind, however, that irrigation should be considered as short range and used only to establish the vegetation.

3. Plants must be adapted to **local temperatures**—daily maximums, minimums, and averages.

4. Plants must be adapted to **elevation**. This factor often affects the length of the growing season. Generally, as elevation increases, the growing season decreases.

5. Plants must be adapted to the **slope**. For example, when shallow rooted plants are not suitable for stabilizing a steep hillside, deep-rooted species are recommended. Slope angle primarily influences soil stability and the amount of incident solar radiation received.

6. Plants must be adapted to **aspect**. Plants that do well on an eastern exposure may not survive on the southern side of the same hill. Aspect, or exposure, affects day length, solar radiation loads, and growing season length.

7. Plants must be adapted to local **wind** velocities. Wind may cause severe water stress in plants, and may affect growth habit, pollination, and structure.

8. Other factors that should be considered are: potential **fire** risk, and potential invasion of **weeds**, and **animals** that may invade the site. Both pests, such as rodents or grasshoppers, and beneficial animals, such as those that will aid in seed dispersal, should be considered. Some plants are so totally dependent on animals for seed dispersal that the reason a plant is seen on a site is because of the animals inhabiting it. This is an example of a beneficial symbiotic relationship between plants and animals.

- **Time and timing considerations**. The species should be planted to coincide with expected moisture, using a fast rooting species where erosion control is crucial, and integrating the planting time with the mining schedule. When possible, plant immediately after the spoils are graded, unless settling is needed for stability.

- **Species compatibility**. In general, mixtures of various adapted grasses and forbs are desirable because they offer a greater range of adaptation. For example, grasses and forbs provide protection against surface runoff and erosion more quickly than do shrubs and trees. Shrubs and trees, however, provide protective cover, resting places, and feed for certain types of wildlife. Other examples of mixtures include warm-season and cool-season grasses, fast growing and slow growing grasses, and forbs and grasses. Especially on sites where the environment can change every few feet, mixtures may include species adapted to each of the different microclimates, moisture levels, and soils. For example, on low fertility sites, it is advisable to include adapted species with low nutritional requirements or those able to fix their own nitrogen. The result of using a well-planned mixture can be a fast establishing, thick, long-term cover that is less vulnerable to pests, disease, drought, and frost.

> **Exception:** The vegetation specialist should realize that mixtures can sometimes cause competition problems. For example, mixing annuals and perennials is risky if the annuals will force out the perennials; therefore, if they are mixed, use only 10 percent or less annuals in the mixture. Two other approaches to solving a potential competition problem are (1) to seed competing plants in alternate rows or strips; (2) to interplant with shrubs and trees following scalping to reduce grass competition.

- **Mechanical limitations**. The selected species should either lend itself to commonly used planting methods, or a planting method should be developed to handle the desired species. (See chapter 5 for more on planting methods.)

- **Seed and seedling availability**. In choosing species, an important factor is their availability. The availability of seeds, container-grown plants, bare-root stock, cuttings, or wildings should be determined. (See chapter 3 for a more complete

discussion of plant material availability.)

• **Maintenance after planting.** While planting a persistent perennial species is of paramount importance, it is also desirable to identify low-maintenance plants because periodic maintenance after planting can be costly. The ideal low-maintenance species would be self-generating, long-lived, disease-resistant, pest-resistant, and require no refertilization or long-term irrigation. Of course, these characteristics are idealistic, and some postmining treatments may be required for many years to maintain a planting. (See chapter 7 for more details on site maintenance.)

• **Cost.** The cost of seeds is usually low compared to the cost of grading and seedbed preparation. Containerized plants, bare-root stock, and seed of native species are more expensive than commercial seed varieties. Rehabilitation personnel should be aware of cost factors when making species recommendations.

Considering all of these criteria, what approach should be taken in selecting the species?

Several approaches are useful, including referring to baseline information regarding the species found on the site, relying on the experience of others in the field, directly observing old disturbed sites on which revegetation has naturally occurred, and referring to information available from researchers.

Discussion:

Relying on the experiences of others can be useful if they have been able to revegetate a site and they have identified some species that appear to be adapted and others that do not. Direct observation of old disturbed sites which have characteristics similar to the site being rehabilitated, however, is probably a more reliable way to identify successful species (fig. 3-5). For example, plant colonization and primary succession can be observed on old road cuts, old road fills, old mines, overgrazed areas, and so on. Of course, these sites should display the same climatic and soil conditions as the area undergoing rehabilitation. But the reason such observation is so valuable is that it focuses on those species that have naturally adapted to the disturbance and provides information on natural selection and plant succession.

Generally, the vegetation specialist should look for species that are on the low end of the successional scale because they will more actively colonize a disturbance. Some of these primary species have been identified in available literature. If the exact species is not known, pri-

Figure 3. Natural plant succession on an abandoned road in the La Sal Mountains, Utah.

Figure 4. A 15-year-old drill site on the Beartooth Plateau, Montana, showing succession.

Figure 5. A 25-year-old exploratory trench cut, showing grass, sedge, and forb succession.

mary successional species are generally the first ones that appear on a disturbed site. Observation of a site that is just beginning to show vegetation will aid in identifying these species.

> **Exception:** Although revegetation personnel may have to begin with primary species in very harsh conditions, such as alpine tundra, in more favorable soil and weather conditions, they do not have to begin at the lowest stages of succession. Fewer species are adapted to the harsh conditions of the alpine and desert areas, and more are adapted to temperate climates.

Once adapted species have been identified on an old disturbance, a seed collection program can begin, and the seeds taken to a controlled environment, such as a greenhouse, for testing. Considerations in testing include the following:

- Although the species may seem to be a commonly known one, it may, in fact, be a hybrid or ecotype that has developed in order to survive on the disturbed site. If this is the case, seeds from other sources of the same species may not be successful on the mined site. Plant breeders can help determine whether or not hybridization exists by analyzing the plants genetically. If hybridization does exist, the vegetation specialist should consider obtaining his parent material sources directly from the old observed site and breeding it in the greenhouse or nursery.
- Some of these species, especially native species, have low vigor, low germination rates, and low productivity; thus, greenhouse or nursery cultivation is recommended to improve these characteristics and make transplanting to the mined site more successful.
- The species must also be tested to determine whether they will adapt to the mine spoils, whether they have tolerance to drought, and whether they will respond to rehabilitation techniques such as fertilization, liming, and mulching.

If these tests are positive, it is quite likely that the species will be very favorable for revegetation.

Two sources of research information on species selection are:

- The National Agricultural Library in Beltsville, Md., and the Science and Education Administration/Cooperative Education's Western Regional Coordinating Committee are developing a "Computerization of Mineland Plant Species in the Semiarid West." When completed, this system will allow the vegetation specialist access to data and information on the ecological parameters of species of plants that exist on mine spoils or on premined sites. The specialist will be able to query the system in two ways: (1) by listing several species recognized on the site in question, and the system will then give information on other species adapted to the area; or (2) by listing precipitation, annual temperatures, and soil conditions, and the system will supply a list of plants that should grow in that area.
- New plants are also being developed by scientists. Generally hybrid, these strains consist of improved natives, improved introduced species, and a combination of the two. These genetically new species should be considered when available.

Additional Information:

For more information on "Computerization of Mineland Plant Species in the Semiarid West," contact Reclamation Research, Montana State University, Bozeman, Mont. 59717.

For more information on the hybrid breeding program, contact Crops Research Laboratory, Utah State University (UMC-63), Logan, Utah 84322.

For information on a computer-based tool to retrieve information on more than 4,000 plants, native and introduced, in the states of Colorado, Montana, and Wyoming, contact Plant Information Network (P.I.N.), Dept. of Botany and Plant Pathology, Colorado State University, Fort Collins, Colo. 80523.

For more information on species selection, refer to "Plant Materials for Use on Surface Mined Lands in Arid and Semi-Arid Regions," USDA Handbook. Soil Conservation Service (SCS-TP 157), Lincoln, Neb. (in press).

For information on selecting adapted species for high-elevation and alpine tundra sites, see: "Rehabilitation of Alpine Tundra Disturbances," by R. W. Brown, R. S. Johnston, and D. A. Johnson. J. Soil and Water Conserv. 33:154-160. 1978.

Chapter 3
PLANT MATERIALS

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Once the plant species have been selected, the vegetation specialist must determine what kind of plant material should be used, where it can be obtained, and how it can be stored. These decisions should be made as early as possible, because certain seeds are difficult to obtain, and other types of plant materials, such as bare-root or container-grown plants, may take months or years of cultivation before they are ready for planting. This chapter will discuss basic considerations for choosing plant materials. Seeds, bare-root stock, containerized seedlings, cuttings, sprigs, rhizomes, plugs, and wildings will be discussed; the chapter will also reference sources of information specific to the species chosen for revegetation. The selection of one type of plant material over another depends on site requirements; however, the vegetation specialist should consider using a variety of stock. Also note that grasses, as well as forbs and shrubs, lend themselves to various types of planting stock.

SEEDS

When should seeds be used?

Seeds are generally the least expensive plant materials; thus, they should be used when the species germinates easily and sufficient moisture for germination is expected. (Seeds usually need 7-10 days in a moist, warm soil to germinate and establish.) Other conditions on the site must also be favorable to seeding.

Exception: In some cases, for example, when erosion is an extreme problem or under arid conditions, transplants may provide a more effective ground cover than that attained from developing seedlings.

Where can seeds be obtained?

There are a variety of sources for seeds; however, the vegetation specialist must realize that not all seed sources will be satisfactory. The environmental conditions under which a particular plant species has evolved can affect its success on a site having a different environment. Seed types and varieties should be chosen with this fact in mind.

Discussion:

The vegetation specialist should not limit himself to buying seeds from a local dealer if seed dealers in other areas have developed a seed source that more nearly meets his needs. On the other hand, seeds should not be purchased simply because the seed variety is cheaper. The cheaper seed may not be adapted to the soils or climate of the mined site. Contact Forest Service regional reclamation specialists, Soil Conservation Service (SCS) personnel, county agents, State agricultural experiment stations, or other rehabilitation specialists for specific suggestions. Also note the references in "Additional Information" at the end of this chapter.

Common sources of seed include:

- **Plant materials centers.** Soil Conservation Service-sponsored centers have developed improved plant varieties and some centers specialize in growing native and introduced plant materials useful on mined areas. At times, they are producing enough foundation stock to distribute through SCS outlets for demonstration plantings. This, however, is a limited supply source.
- **Commercial seed suppliers.** After the SCS tests and develops plants, seeds are made available to private growers who, in turn, produce

the seed and sell it through major seed companies. These suppliers, however, often do not have all varieties and species useful for mineland revegetation. It is expected, though, that as demand for such seed types increases over the next few years, supply will increase markedly. When purchasing seed, insist on information on seed sources and germination tests completed by official seed-testing centers.

- **Small, private seed collectors.** There are numerous small local businesses that will collect native seeds. These collectors will work under contract to harvest seeds for specific projects. Lists of these collectors are available from the Soil Conservation Service, State universities, and Forest Service offices.
- **Personal collection effort.** When other seed sources do not have seeds of the species required to revegetate the site, Forest Service or mining rehabilitation personnel can collect their own seed from native stands (fig. 6). It should be noted that this can be done fairly quickly; for example, it is not uncommon for one person to collect 200-300 lb of fourwing saltbush seed in a day.
- **Seed banks.** An extension of the individual collection idea is to develop a seed bank; that is, acquire seeds in season and store them for future use. This can be a useful practice when a mining company knows in advance what its seed needs will be during the next several years, if the seed species can be stored conveniently and properly, or if the species produces sporadic seed crops.

How should seeds be collected?

Methods of seed collection vary greatly, depending on the species. General suggestions follow and references at the end of the chapter will guide the vegetation specialist to sources of information giving more detailed instructions.

Discussion:

The following guidelines are suggested for collecting seeds:

- Collect from an environment as nearly identical to the site being revegetated as possible.
- Collect at the seed's optimum ripening time, and within a time period that will allow the seed to remain viable until planting. For example, some seed can only be stored for 6 months, whereas other seed can be stored for several years.
- Collect before, not after, storms. Ripened seeds are often disseminated by winds preceding storms.
- Test the viability of the seeds by cutting and examining a sample number. Generally, seeds that are filled are viable.
- Collect from a number of plants of the same species to obtain genetic variability.
- Correct handling of the seed is important from the time it is collected. Some rules of thumb: Cloth bags are better for collecting and storing the seed than are plastic bags (fig. 7). Unless recommended otherwise, keep the seeds cool and dry. The seeds should be cleaned and processed promptly after collecting.
- Instruct collectors on proper methods for collecting seed.

Additional Information:

For information on seed-collection equipment, contact the USDA Forest Service, Missoula Equipment Development Center, Fort Missoula, Mont. 59801.

How should seeds be cleaned and dried?

Generally, it is advisable to let commercial seed dealers clean and dry seeds because they can do this job more economically. Major seed companies also have the equipment needed to clean most seeds.

Discussion:

Seeds should be cleaned soon after collection to maintain viability. Weeds, insects, and trashy material must be separated from the seed. The seeds should then be dried to a proper moisture content.

Drying can be accomplished by spreading the seeds in a thin layer over tarps or plastic sheets and leaving them exposed to the sun for several days. The seeds should be stirred each day. If collected in the fall, the seeds can be placed in a cool, protected building for drying.

What other seed treatments are necessary?

Some seeds require a chemical treatment if they will be stored for extended periods of time; seed inoculation may also be required.

Figure 6. Collecting seeds from adapted species.

Discussion:

For specific information on treating seeds with fungicides or insecticides, consult seed publications or Soil Conservation Service and State university scientists.

Most commercial seed growers will inoculate legume seeds with nitrogen-fixing micro-organisms as part of a standard seed treatment. The vegetation specialist should check to make sure this has been done. Native legumes may require a different kind of inoculation than those used for introduced species; commercial seed growers should be able to advise the vegetation specialist on this. Cost of inoculation is minimal and the treatment is highly beneficial.

It is also known that inoculants other than the ones commonly used by commercial processors are important in the successful establishment of certain species. At this time, however, these micro-organisms (for example, endomycorrhizae), are not available commercially, and the vegetation specialist will have

Figure 7. Collecting seeds from a large shrub.

to rely on topsoil or soil adjacent to the mined site to supply these organisms.

It is generally better to inoculate seeds just prior to planting them. If the vegetation specialist wishes to store inoculated seed, he should check available literature or consult commercial seed growers on the length of time the inoculated seeds can be successfully stored.

How should seeds be stored?

After cleaning, drying, and other treatment, the seeds should be stored as directed by seed experts or as advised by available literature. This information is quite specific because seeded species react differently to temperature and humidity. The seeds should also be accurately labeled.

Discussion:

While detailed species information is necessary, some general guidelines on seed storage are as follows:

- Keep freshly collected seeds dry and do not expose them to high temperatures.
- While berry seeds are being cleaned they can be held in small (10 lb or less) bags or spread in a thin layer on trays and kept in a refrigerator or walk-in cooler at 34-40° F.
- Properly dried seed may be stored in unheated buildings for several months with little effect on seed viability. Seeds can be kept for longer periods by storing in airtight containers at temperatures between 33° and 38° F. Airtight glass or metal containers are preferable to plastic bags.
- Avoid high humidity and high temperatures; if bagged seed becomes wet by accident, open it immediately and thoroughly air-dry the seed.
- Guard against rodents.
- Facilities such as the National Seed Storage Laboratory at Fort Collins, Colo., can provide information on long-term seed storage; however, in most cases, land managers and mine operators concerned with revegetation will not need to store seed for more than 6-18 months.

Proper labeling is crucial because such records will later help identify which species are best adapted to the site. In general:

- Place labels on the inside and outside of the container. Include: (1) precise species name; (2) seller's or collector's name; (3) date of collection; (4) detailed information on location of seed source.
- In the office, a complete file should be maintained on all seeds. This file should include: (1) all information on the seed container labels; (2) information on germination tests, purity, and pure live seed percentage; (3) characteristics of the site from which the seed was collected; (4) where and when, precisely, the seed was planted; and (5) what dates the collector recommends for future seed collections.

CONTAINER-GROWN PLANTING STOCK

When should container-grown planting stock be used?

Generally, container-grown planting stock (fig. 8) is recommended on harsh sites such as rocky areas or toxic soils; where establishment may be difficult due to erratic or low precipitation; where a fast developing ground cover is important; or where the higher cost of this stock is offset by its superior survival rate.

Discussion:

Container-grown planting stock often has a greater chance of success than is achieved by direct seeding because the period of time from seeding through germination, emergence, and early growth is bypassed (fig. 9). Thus, quick plant establishment is obtained.

Container-grown stock has some advantages over bare-root stock. Container-grown stock can be grown more quickly by suppliers, often the root system of container-grown planting stock is better protected during planting, and survival of certain species has been increased. Also, bare-root planting stock is not available at certain seasons.

The disadvantage of container-grown stock is that some species adapted to mine sites are difficult to cultivate as container stock. Container stock is quite heavy, which presents shipping and handling difficulties, and it may also be more expensive (fig. 10). Container stock is also difficult to maintain from the time it is delivered until field planting is completed. Proper storage areas, watering facilities, and daily care are needed.

Where can container-grown planting stock be obtained?

Limited supplies are available from Forest Service nurseries and State nurseries; private growers also produce such stock.

Discussion:

Of course, some species are more readily available than others. If a desired species is not being cultivated by the nursery, reclamation specialists may be able to provide seed to the nursery. The seed should first be tested for germination.

How should container-grown stock be handled?

In general, the plants must be hardened and kept moist before planting. Specific information for handling individual species should be obtained from specialists having experience with that species.

Discussion:

Hardening is a process done prior to planting to enable the stock to resist cold, heat, or desiccation following planting. If possible, it is desirable for container-grown plants to have been stored outside through one winter season prior to planting; they can usually be kept outside without shelter, if they are packaged in sawdust. If the seedlings are started in the greenhouse during the winter, they may be only 8-10 weeks old when planted in the field. Such young plants should be "hardened-off" for at least 2-3 weeks prior to planting by exposing them to cool temperatures and less watering. If nighttime temperatures do not go below freezing during this time, most plant species will not be killed by frost following field planting. Of course, plants vary in hardiness, and this is one factor to consider in selecting species for revegetation, and in scheduling planting operations. Decreasing the amount of water supplied to seedlings during the "hardening-off" period also helps in toughening the plants.

There is some evidence that very young seedlings are incapable of attaining any freezing tolerance; thus, there may be a minimum age for most plant species, prior to which it is unwise to plant them in the field when chances for the occurrence of subfreezing temperatures are high.

Figure 8. Container-grown seedlings are useful in mineland reclamation.

Figure 9. Containerized seedlings typically exhibit a well-formed root system.

Figure 10. A difficulty in using container-grown stock is its bulkiness.

But presently, there are no standards for size or age of the container-grown plant prior to planting.

BARE-ROOT STOCK

Bare-root stock or nursery-grown stock is usually grown in beds for 1-2 years. After this time, the plants are dug up while dormant, the soil shaken from the roots, and the plants are packaged in moist peat moss in crates. Once taken from the planting beds, bare-root stock can be stored in coolers for as long as a year.

When can bare-root planting stock be used?

Consider using bare-root stock when the species responds to this kind of cultivation; there is sufficient time to propagate the stock; the bare-root plant can be lifted from the nursery during the dormant period; and sufficient soil moisture will be available to root the stock when planted.

Discussion:

Planting bare-root stock provides a means of establishing a fast growing cover on a site; it is less expensive than container-grown stock; and the plants have less need for hardening because they are dormant when packaged. Bare-root plants are easier to ship, plant, store, and handle than is container-grown stock. Most native shrubs and trees can be successfully grown and field planted as nursery stock. On mine spoils, nursery stock has been used very satisfactorily unless the sites are extremely rocky or arid. Only a few woody plants perform better as container stock.

The disadvantages of bare-root stock are that it takes longer to cultivate, and it must be lifted from the nursery and replanted at specific seasons. Also, a few species are not adapted to currently used bare-root cultivation practices.

Where can bare-root stock be obtained?

The same sources that supply container-grown plantings may supply bare-root stock.

Discussion:

Vegetation specialists may be able to provide seeds to nurseries for production of bare-root stock, but often this must be done 1 or 2 years in advance of the projected planting date. Thus, seed collection considerations are also involved in this method of obtaining stock.

How is bare-root stock handled?

Although bare-root stock is easier to ship because it is lighter than container stock, plants should be kept in a cold environment.

Discussion:

- The stock must be lifted from nursery beds while dormant and planted while still dormant (fig. 11). The user should schedule planting on the mine site with the lifting of the stock.
- The stock can be shipped in crates, holding as many as 2,000 plants.
- Plants should be kept in cold storage until planted, but taken out a day ahead of time to harden or acclimatize the stock.
- En route to the planting site, keep the stock shaded, moist, and protected from wind blasts. At all times, avoid exposing crated or boxed stock to sun or other sources of high temperatures, and never allow roots to dry out.

What size bare-root stock should be used?

It is advisable to have roots at least 6-8 inches long so deeper soil moisture is available to the transplant. On the other hand, plants with excessively long roots are difficult to transplant correctly on rocky sites.

CUTTINGS, RHIZOMES, SPRIGS

Cuttings are pieces of stems, usually from a woody plant, that are either rooted and then planted on the site or directly cut from a plant and replanted on the mine site. Rhizomes are underground stems of grasses, sedges, or forbs. Rhizomes can be rooted and replanted. Sprigs are pieces of grasses or sedges that can be rooted and replanted.

When should these types of plant stock be used?

Cuttings are easily propagated and can be successfully established on harsh sites. They provide a ground cover in a short period of time if the species desired are adapted to this kind of cultivation and enough moisture for plant establishment is available (fig. 12).

Figure 11. Harvesting bare-root stock.

Figure 12. One-year-old stem cuttings.

Discussion:

Willows are quite adapted to cuttings. Cuttings are also very compatible with direct seeding. Cuttings must be acquired in season and handled according to instructions outlined for various species. Personnel must be trained to properly cut and store the desired materials. Some nurseries cultivate woody cuttings. If an individual plant is identified as adapted to a toxic situation on a mine site, as many as 100 rhizomes or sprigs can be cultivated from this one plant and transplanted to the site. Sprigs and rhizomes are normally taken from herbaceous plants and started in containers or flats.

WILDINGS, PLUGS

Wildings are individual plants transplanted from the wild to another site. Plugs are usually field-grown, native clumps of vegetation dug up and replanted on another site; they may contain several plants.

When should wildings or plugs be used?

They are especially useful when a species adapted to the mined site does not produce a good seed crop. They have the same advantages listed for cuttings, sprigs, and rhizomes.

Discussion:

The desired plant is dug from a wild site and either immediately replanted on the mined site or taken into a nursery for a year. If nursery grown, segments of the plant can be split from the parent plants and planted on the mine site.

Additional Information:

For more information, refer to:

"Restoring Big-Game Range in Utah," by A. Perry Plummer, Donald R. Christensen, and Stephen B. Monsen, Publication No. 68-3, Utah Division of Fish and Game, Ephraim, Utah. 1968.

"Collecting and Handling Seeds of Wild Plants," by N. T. Mirov and Charles J. Kraebel, Civilian Conservation Corps, Forestry Publ. 5. 1939.

"Woody-Plant Seed Manual," U.S. Dept. of Agric., Misc. Publ. 654. 1948.

"Plant Materials for Use on Surface Mined Lands in Arid and Semi-Arid Regions," USDA Handbook. Soil Conservation Service (SCS-TP 157), Lincoln, Neb. (in press).

"Selection, Propagation and Field Establishment of Native Species on Disturbed Arid Lands," Institute for Land Rehabilitation. Utah State Agricultural Experiment Station Bulletin 500. 1979.

"Sources of Seeds and Planting Materials in the Western States for Land Rehabilitation Projects," by Kent Crofts and C. M. McKell, Utah Agricultural Station Land Rehabilitation Series No. 4. 1977.

Chapter 4
SITE PREPARATION

Chapter Organizer: Bland Z. Richardson

Major Contributors: Bland Z. Richardson, Paul E. Packer

Prior to planting, adequate site preparation is essential to provide an environment that will be within the physiological tolerances of the plants and to eliminate erosion problems. Even though the vegetation specialist may not know the specific tolerance limits of the species selected for planting, he will know enough about them to advise on the site conditions necessary for planting.

Site preparation can include both physical and chemical treatments. For example, because most mine spoils become compacted, they should be ripped and then harrowed, or, if the spoil is toxic to the vegetation, a chemical treatment may have to be applied.

Shaping and grading the mine spoils as types of site preparation are discussed in the "User Guide to Soils," USDA For. Serv. Gen. Tech. Rep. INT-68.

PHYSICAL SITE PREPARATION

For the purposes of this discussion, physical site preparation will be referred to as tillage. Tillage is defined as those mechanical and soil stirring actions carried on for the purpose of establishing the plant.

Why is tillage important?

Proper tillage will provide a suitable environment for seed germination, root growth, weed control, soil erosion control, and moisture control.

Discussion:

Tillage can achieve this goal by:

- Providing soil aeration.
- Incorporating the fertilizer into the soil.
- Incorporating mulches or plant residue into the soil.
- Providing runoff control and a loose surface for good moisture infiltration.
- Reducing compaction, which restricts water movement.
- Providing a looser, cooler, more moist soil for seed germination.
- Providing good seed-to-soil contact.
- Controlling erosion through contour tillage and contour planting.
- Providing a temporary modification of spoils conditions, such as density, aeration, and moisture-retention capacity.

What tillage operations are necessary?

Tillage operations are usually divided into primary and secondary operations and both are necessary. The choice of tillage equipment depends on site and spoil conditions. Contrary to previous belief, however, spoils need to be worked only enough to insure optimum vegetation production; any tillage activity beyond that is of questionable value.

Discussion:

Primary tillage cuts and shatters the spoil and may bury trash by inversion, mix it into the tilled layers, or leave it basically undisturbed. It is a more aggressive and a relatively deeper operation, and thus usually leaves a rougher surface. Shallow and deep ripping (fig. 13), some kinds of disking, chisel plowing, and stubble-mulch tilling are types of primary tillage operations used in surface mine revegetation.

Ripping.

- Deep ripping will shatter spoils packed during placement; shallow ripping will break up impervious spoil layers below the normal tillage depth to improve water infiltration, drainage, and root penetration. Both shallow and deep ripping will allow more vegetation production,

Figure 13. Rippers are very effective in breaking up the compacted spoils typical of mined sites.

Figure 14. The spoils should be dry enough to permit the ripper teeth to shatter the hard layer.

thus increasing the amount of organic matter in the spoils.

- If the spoils have been placed using a scraper or similar equipment, the spoils should be deep ripped.
- If spoils placement is accomplished with a dragline type operation and graded out with a crawler tractor, then the spoils may need to be either deep or shallow ripped, depending on compaction. Shallow ripping is from 12-18 inches deep.
- On slopes where spoils are dumped downslope on angles of repose and later are graded out with a front-casting dozer, the dump from which the graded material was taken should be at least shallow ripped and may need to be deep ripped.
- Deep ripping should not be practiced on downslope dumps if it has been determined that ripping may later cause surface instability, which would lead to mass slumping.
- If a dump has been in place for more than 1 year before planting, it should be ripped.
- If a dump was ripped prior to seeding with an annual cereal species to protect the surface from erosion until a permanent cover could be planted, subsoiling or shallow ripping will probably not be necessary prior to permanent planting.
- Always rip dumps on the contour.
- Prior to ripping, the spoils should be relatively dry to permit shattering of the hard layer (fig. 14); if the spoils are wet, only a thin slot, which may reseal very quickly, will be sliced through the spoils.
- Spoils below the ripped layer must have adequate water-retention capacity or there will be no place for surface water to go, and the rip marks will become saturated. If this occurs, the rip marks will not trap the air needed for plant-root growth. Vertical mulching can help solve this problem. In vertical mulching, the ripped slit is filled with mulch so that the ripping marks or slits stay moist but not saturated. In addition, a subterranean form of erosion called soil piping may occur.
- The deep spoils that are ripped and brought to the surface must not be so acid or alkaline so as to discourage root growth.
- Subsoilers should not penetrate into a deep layer of sand if the water table in the sand drops rapidly during dry weather.

• Spacing between standards of the ripper can vary. In general, the best spoil fracturing is obtained by adjusting the distance between the standards to approximately equal the depth of the rippers.

• Tractors and heavy implements should not be driven over the rip marks to prevent resealing of the slit by tire compaction.

Disking.

• Disk tilling is especially useful when the spoils have an established vegetation cover. Disk tilling will produce a mixing action of the spoils rather than inversion.

• Disk harrowing can be used for primary tillage.

Chisel plowing.

• Chisel plowing will penetrate heavy spoils, shatter compacted layers, and break up large clods. When the surface is left broken and open, it will catch and hold rainfall and resist wind erosion. Chisel plowing is probably one of the most useful tillage operations in mine spoils revegetation work.

Stubble mulch tilling.

• Stubble mulch tilling provides a more complete cutting and mixing of trash and deep shattering of the spoils in one operation than either disk harrowing or chisel plowing alone.

Secondary tillage works the spoils to a shallow depth, provides additional pulverization, firms the spoils, closes air pockets, kills weeds, and helps to conserve moisture. Disk harrowing, roller harrowing and packing, and tooth-type harrowing are secondary tillage operations.

Disk harrowing.

• Disk harrowing works extremely well for seedbed preparation, but may not be as effective as the S-tine cultivator harrow on spoils. Spoils that have been disk harrowed are more subject to wind and water erosion.

Roller harrowing and packing.

• This operation is done by roller harrow-packers, also known as cultipackers, cultimulchers, soil pulverizers, or corrugated rollers. It is more effective when used to prepare a seedbed in spoils that have been previously worked while wet. The packer wheels crush the clods, and the harrow teeth bring up more clods, which are subsequently broken by the rear packer wheels. In addition, if the spoils below the surface are a little too wet for good seedbed preparation, repeated trips over the spoils with the roller packer will continue to bring the moist spoils to the surface for better drying. The big advantage of roller harrowing and packing is that it breaks clods, pulverizes and firms the spoils, and closes air pockets. It is effective for preparing a seedbed for range drills.

Tooth-type harrowing.

• This is probably the most versatile of the secondary tillage operations. For example, spring-tooth harrowing can be made to work 3-6 inches deep to loosen spoil crust, and dig, lift, and break clods. If used immediately after ripping, it closes air pockets in the spoils, breaks up clods, and levels the surface to make it ready to plant. Its deeper penetration into crusted spoils and its more aggressive action make spring-tooth harrowing better suited for seedbed preparation than spike-tooth harrowing.

What kinds of equipment are required to carry out tillage operations?

Equipment considerations should be based on the following:

• *Equipment that must be bought versus operations that can be contracted.*

• *Possibility of using farm or mining equipment for mineland revegetation work.*

• *Capability of the machines.*

• *Machine size needed for the site.*

• *Cost of the equipment and its useful life.*

• *Training and manpower required to operate the machinery.*

• *Conditions of the site and treatments required.*

Discussion:

Because of the expense involved in purchasing revegetation equipment compared to the relatively small acreages that are usually involved, contracting out tillage operations may be more economical.

The disadvantage of using mining equipment is that even in cases where it is suitable—such as using a dozer to pull tillage equipment—it may be impossible to count on its availability because its primary use is for mining operations. The disadvantage of some farm machinery is that it is not rugged enough to withstand spoils conditions and the terrain of the mined site.

Various tillage operations have already been discussed, and equipment can be chosen accordingly. But it is also important to note that the

equipment used to pull the tillage machinery is another consideration:

- The small crawler tractor with a wider-than-normal beam between tracks is safe for cross-slope work as steep as 2:1 or on very rough sites. This tractor should be equipped with a hydraulic ripper and a hydraulic three-point lift at the rear.
- On extremely steep, rough slopes, a large crawler-type tractor may have to be used to pull the tillage equipment. The deep ripper is usually pulled by a large crawler tractor.
- Farm-type wheel tractors should be used only if slopes are not too steep. The advantage to farm-type wheel tractors is their greater handling flexibility.

When should tillage operations be done?

Ideally, site preparation should be done as soon as the mined site is shaped and just previous to planting. The general sequence of site preparation is to: (1) rip; (2) disk or harrow; (3) fertilize; (4) harrow in fertilizer; and (5) plant.

Discussion:

In some cases it may be necessary to quickly treat the site and plant a fast establishing vegetative cover on the site to prevent wind and water erosion. If so, a second site preparation will be necessary prior to permanent planting.

Treatments will also vary depending on the site being revegetated. For example, on dumps that have produced weeds prior to permanent planting, the following methods have been recommended.

Where wind erosion is a problem, keep seed heads from maturing by clipping; otherwise, spray herbicides to kill undesirable plants just prior to maturing. Then, plant directly into the spoils with a drill. The stubble-mulch tiller will be very effective when it is desired to mow the weeds and mix a portion of the trash into the spoils, and yet leave enough exposed to control wind erosion.

In areas where wind is not a major problem, use a narrow chisel point to plow as deeply as possible, harrow with a flexible tine cultivator, and plant with a grass seeder packer or drill. The flexible tine cultivator breaks crust, kills weeds, closes air pockets, and leaves the ground ready for planting.

As a specific example, the following site preparation techniques were used at a coal mine site in Montana (fig. 15-23):

Once the dragline spoils were regraded for final reclamation in the fall, they were ripped with a number 16 Caterpillar motor grader for

Figure 15. Ripping spoil.

Figure 16. Laying down topsoil.

Figure 17. Ripping topsoil.

better moisture and root penetration. A 20-inch layer of topsoil was laid down and then ripped with a Howard V-chisel to a depth of 14-16 inches to loosen the packed topsoil caused by scrapers and to promote better root and moisture penetration. An "Athens" 126 series, heavy duty, 26-inch offset disk was used to further prepare the seedbed. Commercial fertilizer was applied and a "Kongskilde" triple-K-cultivator harrow with "S" curved tines was

Figures 15-23. Site preparation sequence. (Dwight Layton, Decker Coal Mine)

Figure 18. Disking.

Figure 19. Fertilizing.

Figure 20. Harrowing.

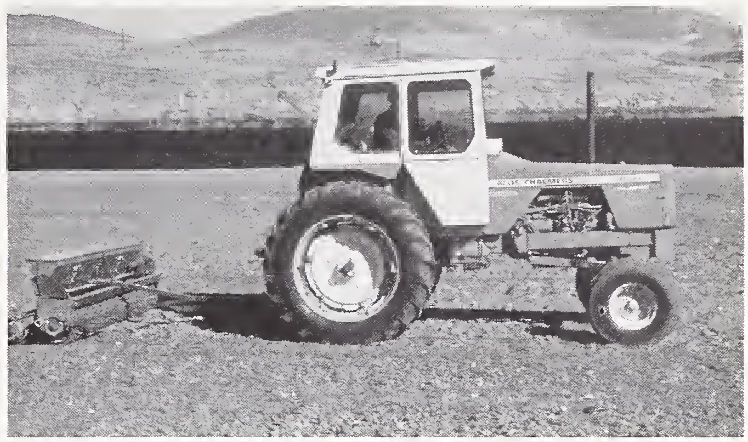

Figure 21. Seeding.

Figure 22. Hydromulching.

Figure 23. Results.

used in the final seedbed preparation to incorporate the fertilizer into the root zone area of the seedbed. The site was planted using a Brillion seeder packer.

OTHER SITE PREPARATION

In addition to tillage, site preparation work may include a program to ameliorate spoil conditions unfavorable to plant growth, such as highly acidic or highly alkaline spoils. Both physical and chemical means can be used to improve these conditions.

When are treatments necessary?

Whether or not the site requires treatments to correct an acid or alkaline condition depends on the spoils' characteristics, as indicated by analysis, and the capability of the desired plant species to adapt to these conditions.

Discussion:

Chemical properties of the spoils are a major consideration for revegetation of disturbed sites because acid and alkaline spoil conditions frequently occur in the West. Acid-mine problems are most often associated with ore production from geologic materials containing sulfide minerals, such as uranium, lead, copper, cobalt, iron, chromium, platinum, and other metals. Alkaline spoils are common to western mining operations. These problem areas are generally found in arid and semi-arid regions where precipitation is insufficient to leach out salts, although they also occur in poorly drained, low lying areas and high water-table areas due to slow leaching.

The parent material from which soil develops controls, to a large extent, the chemical properties of the soil. The productivity of the soil may also be altered by the action of climate and vegetation. Chemical properties modify the soil's physical properties, and the chemical nature of the soil controls the supply and availability of mineral nutrients for the growth of plants and the relative acidity or alkalinity of the medium. The revegetation of such mine sites requires physical and chemical treatments prior to planting as well as selection of adapted plant species. Thus, the role of soil chemistry cannot be overemphasized for successful reclamation of disturbed mine sites.

Soil pH tests can be run to determine whether a soil is acidic or alkaline. Soils vary widely in pH. The extreme range that might be recorded could be from 3 to 10. Most soils fall in the range from 4 to 8.3; most productive soils from 5.5 to 8.3, although some sensitive plants may show chlorosis (yellowing of leaves) above pH 7.5.

• **Acidic soils.** Soils on the acid end of the scale—even the ones at pH 3—produce some kinds of plants. At the extremes of acidity, however, production is low and the number of species is somewhat restricted. In fact, the species contained in a plant community are determined as much by acidity as by any other single soil property.

The influence of acidity on plant growth is not generally thought to be associated with hydrogen ions as such, but to the influence of acidity on the solubility and plant availability of nutrient elements, such as iron, aluminum, manganese, and phosphorus. Poor growth at very low pH's may not be due to excessive hydrogen-ion concentrations, but to an excess and toxicity of iron and aluminum, which are very soluble at such acidity levels, and to the lack of phosphorus, which is insoluble under such conditions.

• **Alkaline soils.** Soils in arid areas will tend to be basic or alkaline and to remain so because of the lack of water needed to leach the basic ions after replacement by hydrogen and the presence of a reserve of basic ions (lime). Plant growth on alkaline soils is directly related to the presence of hydroxyl ions as well as the solubility and availability of mineral elements.

High salt concentrations reduce the uptake of water by plants, retard their growth, and may reduce the uptake of nutrients by plants. High concentrations of some salts, such as boron, can even be toxic to plants. The amount of soluble salts that may impair plant growth depends on the type of salts, the type of soil, and the species of plant. Arbitrary guidelines, however, have been established by the U. S. Salinity Lab staff. A soil is considered saline if the electrical conductivity (EC) of a saturated extract is 4 mmho/cm.

Sodic soils are a specific type of salt-affected soil. They occur when sodium ions are so con-

centrated in the soil that they may adversely affect plant growth. The percentage of sodium ions a soil can exchange with other salts is called the exchangeable sodium percentage (ESP), and if this figure is 10 percent or higher, the soil may be sodic.

Another lab measurement of a sodic soil is its sodium adsorption ratio (SAR). If the SAR is 10 or more, the soil may be sodic.

Sodic soils are highly alkaline. They may be impermeable to water and may crust when dry. Any soil with a pH above 8.5 should be suspected of containing sodium. A soil dominated by calcium seldom will exceed pH 8.3. A soil having a pH of 10 will generally not grow plants, will probably be dispersed, and will be extremely difficult to manage.

Based on the determination that a soil is either acidic or alkaline, a program can be undertaken to correct the soil condition if it is known that the type of plant species to be grown on the site will not tolerate the soil. Certain plant species, however, will adapt to acidic or alkaline conditions. For example, some pine trees prefer a slightly acidic soil with a pH of 5.5 or 6; many grasses prefer slightly alkaline soils. This is because soil pH affects the ability of the plants to take in nutrients (fig. 24), and various species need different amounts of these nutrients.

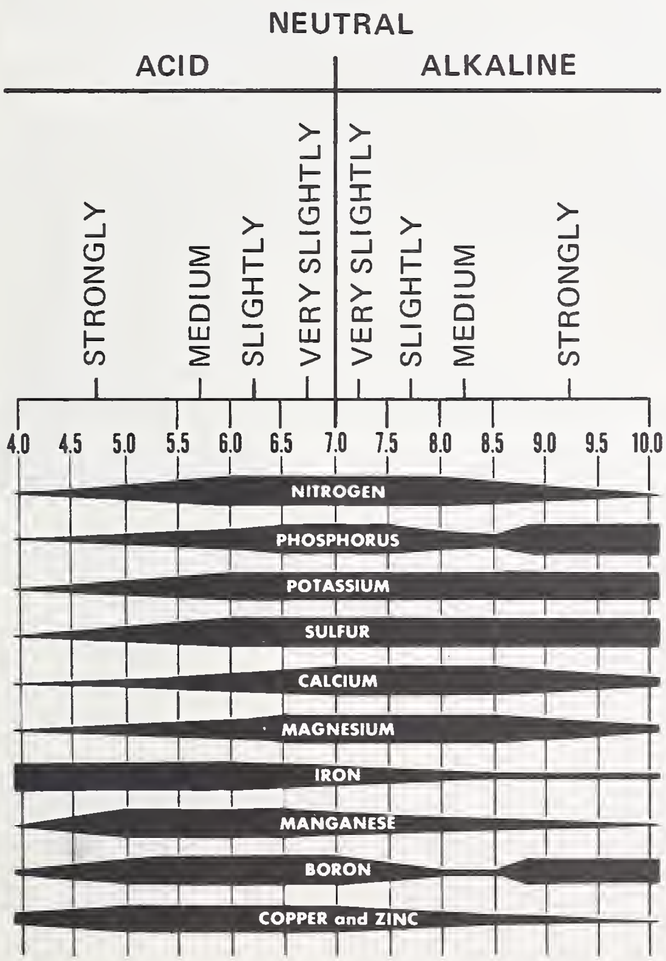

Figure 24. How pH affects nutrient availability. (Texas Agricultural Extension Service)

Consult plant physiologists, county agents, or the Soil Conservation Service to determine if the plant species desired will be adversely affected by the soil conditions indicated by soils analysis. If this is the case, apply appropriate treatments.

How is an acidic soil treated?

In addition to certain physical treatments, adding lime to the soil is the most common chemical treatment for acidic soils (fig. 25).

Discussion:

Physical treatments to correct acidic conditions can include the addition of organic matter to the spoil. Topsoiling is another treatment that adds organic matter as well as burying spoils deeper, thereby further reducing oxidation.

Whenever acid-producing spoils are ripped or harrowed, lime must be applied to the depth of the soil disturbance. Such application will maintain a neutral soil as oxidation takes place. Be-

Figure 25. Preparing to lime acidic spoils.

cause acid soils and acid drainage water both result from the oxidation of minerals (such as sulfides) located on or near the soil surface, the stability of surface materials is also a major influence on acid production. Thus, control of erosion merits special consideration in reducing high concentrations of acids in the soil. Establishing a quick growing vegetation on the site is probably the best way to control erosion and slow acid production.

Lime can be added to the acidic soil in these forms:

- Ground limestone, or calcium carbonate.
- Burnt lime, or calcium oxide.
- Hydrated lime, or calcium hydroxide.
- Lime residue from sugar-beet processing.

To determine what type of lime to use, several considerations are involved. Ground limestone is very insoluble in water but quite soluble in an acid. It should be mixed at least 10 inches deep into the spoils. Therefore, if a long-range effect is desired, use agricultural limestone. Calcium oxide and calcium hydroxide are forms of lime that are very soluble in water. These forms can be used for an immediate effect but would not be long lasting. For example, ground limestone (calcium carbonate) was used on the Blackbird, a copper-cobalt mine in Idaho that receives 25-40 inches of precipitation annually. Particle size ranged from 200 mesh to 3/8 inch. This variation will permit longer effectiveness of the calcium carbonate in treating acid spoils. The calcium carbonate used on the Blackbird is expected to remain active for at least 10 years.

In addition to correcting a low pH, lime will:

- Improve the physical condition of soil.
- Add calcium to the soil.
- Accelerate decomposition of organic matter, providing for the release of nitrogen.
- Increase fertilizer efficiency.
- Increase nutrient availability.
- Decrease toxicity of aluminum and ferric ions.

How is an alkaline soil treated?

Physical treatments include leaching excess soluble salts through irrigation, adding organic matter to the soil, selecting salt-tolerant plant species, and seeding when the soil is well-supplied with water. Chemical treatments for sodic soils involve the addition of either a soluble calcium salt or an acid or acid-former.

Discussion:

Chemical treatments are generally reserved for sodic soils. The two most often used chemical types are: soluble calcium salts—calcium chloride and calcium sulfate (gypsum); and acids or acid-formers—sulfur, sulfuric acid, iron sulfate, aluminum sulfate, and lime sulfur.

Soluble calcium salts may be used universally on sodic soils. Calcium chloride is more soluble than gypsum and has a more immediate effect. Gypsum is less soluble, less expensive, and has a more long-range effect. Acids added to soils containing no alkaline earth carbonates may make the soils excessively acidic. Sulfur and sulfuric acid are useful to treat limey soils. Rely on soils analysis for specific types and amounts of amendments to use.

Additional Information:

For more information on treating chemical and physical problems in mine spoils, refer to the "User Guide to Soils," USDA For. Serv. Gen. Tech. Rep. INT-68.

Also See: "Handbook on Soils," USDA For. Serv., FSH 2509.15. Amended July 1969.

Chapter 5
PLANTING METHODS

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Regardless of the type of planting method used, the purpose is the same: to place the seed or plant in contact with the soil, cover it properly, and firm the soil to keep the seed or plant in place and to eliminate air spaces. The vegetation specialist, however, should realize that although many agricultural principles apply to mineland planting, the mine site has a subsurface quite different from rangeland or cropland. Thus, recommendations on times to plant and planting methods may differ from methods commonly accepted by range managers or farmers in the area. Even the esthetics of mineland planting differ from farming. Cluster planting or landscape planting that follows the terrain of the land is preferable to planting in neatly spaced rows across the acreage.

This chapter will give some general guidelines on planting times, seeding methods and equipment, planting other types of plant material, and mixed plantings.

TIME TO PLANT

Planting times will, of course, depend on many factors: the climate; the type of planting stock and soil; moisture needs of the species; frost heaving problems; anticipated erosion problems; sufficient dryness to allow equipment onto the site; and the time of year mining activities conclude. But, in general, planting times should coincide with the longest precipitation season or favorable period of time that may be available for seedling or transplant establishment.

How can the best planting time be determined?

An examination of baseline data dealing with the climatic regime of the area and several years of temperature/precipitation relationships will aid in determining favorable planting periods. This information can be related to the amount of time needed for plant establishment.

Discussion:

Baseline data will help indicate if a region is subject to false plant growth starts; for example, the region may have early precipitation that wets the soil and may initiate seed germination, followed by a long dry period. Of course, this information will be very general and weather conditions may vary in the planting year under study, thus causing a change in planting times. Tables 3 through 6 discuss some of the advantages of fall, winter, spring and summer plantings in four climatic regions; however, as always, the vegetation specialist must realize that these are only general guidelines and weather conditions of a particular year may alter their value.

How should the mine site be treated when the spoils are ready for planting at a time other than the optimum planting time?

If the area is subject to heavy wind and water erosion, the topsoil should be laid on the spoils during a period of low wind and rainfall activity, and it should be seeded with a fast establishing grass that may or may not be the permanent species desired. If erosion is not a problem, the topsoil can be laid down and the planting crews can wait for an optimum planting time. If it is impossible to lay down the topsoil and keep it sufficiently protected, it should be stockpiled until a favorable planting time arrives.

Table 3. — *Time to plant, Northern Great Plains timing matrix*

	Spring		Summer		Fall[1]		Winter	
Activity	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages
Direct seeding[2]	Most optimum conditions probable between early March and late April. Seedlings must emerge before start of spring rains. Topsoil receives best protection at this time	Access can be a problem		Optimum planting conditions have passed—would require irrigation. Postpone seeding to fall	Provides best access and weather for planting. Stratification important to native and shrub seed. More time available to plant	Topsoil and seedbed protection a problem		Seeding on snow is possible but wind may destroy seedling. Seedbed preparation and access are difficult
Bare root	Essential to plant early between frosts and snowstorms so that roots will develop before buds break dormancy. Plant immediately prior to maximum soil moisture season	Timing is very critical		Storage a problem. Seed dormancy broken. Soil too dry. Plants will burn. Lack of necessary moisture	Plants can be planted when dormant and become better acclimated to site if planted after frost	Some species not adapted to fall planting	Not recommended	
Containerized	Most optimum conditions exist very early in spring between frosts and snowstorms	Disadvantage is that stock is usually not ready or available. Access sometimes a problem	Not recommended		Same as above	Same as above	Not recommended	

PROVIDED BY R.C. HODDER

Climate Summary: Considered a continental climate, with warm summers and cold winters. Temperatures can range from -40° F to $+105^{\circ}$ F. Average precipitation about 12 inches, but can vary from 4 to 18 inches annually in various localities. Precipitation dependent on snowmelt and spring rains that fall between April and mid-June. High wind and high evaporation rates common.

[1] Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.

[2] Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded spoils where natural sloughing will cover the seed.

Table 4. — *Time to plant, alpine timing matrix*

Activity	Spring	Summer: Advantages	Summer: Disadvantages	Fall[1]: Advantages	Fall[1]: Disadvantages	Winter
Direct seeding[2] (grasses, sedges, forbs)	Sites not accessible	None	Optimum site conditions have already passed. Site may remain too dry. Seed not yet ready to be collected	Provides for dormancy requirements. Site conditions are usually optimum in fall (e.g., not too wet). Seed will be in place next spring when conditions are optimum	Seed collection of natives may coincide with optimum planting times. Seeds may have to be collected 1 year ahead, or purchased commercially from nurseries. If seeding is too early, frost damage to germinating seedlings may occur	Sites not accessible
Bare-root stock	Not recommended in this life-zone					
Containerized tubelings or native plugs (grass, sedges, forbs, and some shrubs and trees)	Sites not accessible	None	Actively growing plants may not be hardened-off to low temperatures. Conditions not favorable	Plant only after dormancy is induced. Site conditions are usually most favorable	Frost thrusting may lift plants if not firmly packed. High risk of severe storm activity	Sites not accessible

PROVIDED BY R.W. BROWN

Climate Summary: Short growing season of 45 to 80 days; low summer temperatures averaging about 43°F, high wind speeds, high solar radiation loads, and no frost-free periods (needle ice thrusting can occur at any time). Seasons of summer and fall are compressed into about 2 months, and winter and spring together are about 10 months.

[1] Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.

[2] Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded spoils where natural sloughing will cover the seed.

Discussion:

Whenever erosion may be a problem, the topsoil must be quickly protected by some kind of vegetation. So, the vegetation specialist may have to seed with a temporary species at a time of year less than ideal and replant with the desired species at a later date. Economically, the topsoil resource is more valuable than the seed, and it should be given priority. In addition, it is generally better to replace the topsoil as quickly as possible after the mining operation has left the site to preserve the micro-organisms present in the topsoil rather than trying to stockpile it.

When wind or water erosion will not be a problem and the chances of plant establishment are poor, the topsoil can be spread on the site several months prior to planting.

How can the problem of trying to plant at a less-than-optimum time be avoided?

By coordinating the ideal planting time with the overall rehabilitation program, the vegetation specialist may be able to avoid the problem of having to determine whether or not to plant at a less-than-ideal time of year.

Discussion:

Once the ideal time for revegetating has been determined, other aspects of the rehabilitation program should be scheduled for that target date. For example, planting materials should be ordered sufficiently in advance of the planting date. In addition, the mine operator should be encouraged to schedule mining operations to conclude in time to meet optimum planting seasons.

PLANTING SEEDS

Seeds are planted by either drilling or broadcasting. Drilling is a method of planting by which the seeds are dropped from a seeding machine into holes or furrows and then covered with earth. Broadcasting scatters the seed on the

Table 5. — *Time to plant, Great Basin Range and Foothills, and Colorado Plateau timing matrix*

	Spring		Summer		Fall[1]		Winter
Activity	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages	
Direct seeding[2]	Favorable temperature/ precipitation for seedling establishment	Late winter may reduce time available for seeding. Late frost or a short spring may reduce seedling establishment or growth	Not recommended		Seeds may receive needed cold treatment and germinate in late winter	Early winter may prevent completion of seeding operations.	Not recommended
Bare-root planting	Plant can establish if planted before summer drought	A short spring season may reduce survival	Not recommended		Plant mid-fall. Avoid late fall planting	Frost heaving in heavy soils. Open winters	Not recommended
Transplanting container-grown plants	Best results for establishment are in spring. Hazards of seed germination and establishment are bypassed	Weather may be a problem in scheduling field work	Possible if can be planted in moist soil. Long period of planting is possible	High temperatures and drought can be detrimental	Best results for establishment. Plant early to mid-fall	Frost heaving. Open winters	Not recommended

PROVIDED BY CY McKELL

Climate Summary: An area of isolated mountain ranges and extensive level valleys where a highly variable frost-free growing season may be from 120-180 days in the valleys and less than 110 days in the foothills. Spring and fall temperatures are generally moderate (50° F), but high summer temperatures may reach in excess of about 98° F. Warm season precipitation from erratic thunder-showers is less than half of the total precipitation of about 6-16 inches annually.

[1] Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.

[2] Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded spoils where natural sloughing will cover the seed.

ground's surface, and the seeds may or may not be covered with earth in a subsequent operation. Broadcasting also includes hydroseeding and aerial seeding. Both drilling and broadcasting can be done with machines or by hand.

Which method is best for seed planting?

Drilling is the superior method of seeding where site conditions permit; however, in some cases, the site may only be accessible to a type of broadcast seeding.

Discussion:

Drilling is considered superior because the seed will be covered to a proper depth, seed distribution is uniform, rate of seeding is controlled, and soil compaction can be accomplished with packer wheels attached to the drill (fig. 26). Broadcasting is considered less efficient because the seeds often perch on top of the soil where germination and establishment are difficult, if not impossible. Rodents and birds may pick up broadcast seed and eat it or carry it away to a seed cache. Seed that is broadcast should always receive some mechanical treatment to give it suitable coverage unless the bed is loose so that natural sloughing of soil will cover the seed. Table 7 compares these two methods of seeding.

It is recommended that planting be done on the contour to trap available moisture and prevent erosion.

Exception: On slopes too steep for planting equipment, and where ripping has been done on the contour, planting may have to be done up and down the slope, recogniz-

Table 6. — *Time to plant, semiarid timing matrix*

	Spring		Summer		Fall[1]		Winter	
Activity	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages	Advantages	Disadvantages
Direct seeding[2] (grasses)	Cool season species only	Winter moisture variable	Warm season species. More reliable precipitation. Plant prior to July-Aug rains	None	None	Frost heaving. Limited fall growth	None	Unsuitable for germination and growth
Bare root (shrubs)	Not recommended		Plant after initiation of summer rains. Soil moisture must be near saturation	Timing critical. Variable precipitation	If summer rains are late, early fall plantings are possible	Frost heaving	Not recommended	
Containerized seedlings (shrubs)	Not recommended		Soil moisture must be near saturation	Variable precipitation	If summer rains are late, early fall plantings are possible	Frost heaving	Not recommended	

PROVIDED BY EARL ALDON

Climate Summary: Semiarid mesas and valleys of northwestern New Mexico and northeastern Arizona are characterized by low, highly variable rainfall and high summer temperatures. Highest rainfall months are July and August with occasional late summer storms extending into September. Driest months are May and June. Rainfall varies with elevation, but in lower areas averages 7-10 inches annually. Snowfall light most years and seldom remains on ground. Growing season ranges from 140-180 days.

1 Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.

2 Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded spoils where natural sloughing will cover the seed.

ing that some erosion may occur because of wheel tracks.

What steps must be taken when planting seeds?

After the time of year to plant has been determined, the seedbed must be prepared, the equipment selected for either drilling or broadcasting, the seed planted and covered, and necessary cultural treatments, such as mulches or fertilizers, added to the site.

Discussion:

If the site is too steep or rocky for conventional equipment to till it (see chapter 4), the surface should be roughed in some other way to loosen the soil crust and allow the seed to come in contact with the soil. Chaining is one way to achieve this rudimentary type of seedbed preparation.

Exception: Broadcast seeding is sometimes satisfactory without seedbed preparation if the mine spoils are seeded immediately after they are graded and before the surface becomes crusted.

Numerous types of drills and broadcasters are on the market; the following are only a few that have proved successful in mineland reclamation. Selection of specific equipment will depend on their availability, capability, characteristics of the site, and treatment required.

Drilling:

• **Seeder-cultipacker** (fig. 27). Also called the grass-seed planter or seeder-packer drill, the seeder-cultipacker has a fluted feed to meter seed from the hopper. The seedbed is prepared in previously tilled soils by the front rollers, which break up clods and close air spaces in the spoils. Seeds are dropped in furrows formed by

Table 7. — *Seeding methods advantages/disadvantages*

Characteristics	Drilling		Broadcasting			
	Machine	Hand	Hydroseeding	Other Machines	Hand	Aerial
Topography	Steep slopes and access are problems; if slopes are greater than 3:1, broadcasting recommended	Less limited	Can handle steep terrain, depending on distance	May be limited by steep terrain	Less limited	Unlimited
Obstructions	Limits use	Unlimited	Unlimited	Somewhat limited	Unlimited	Unlimited
Compacted Soil	Possible	Possible	Not acceptable	Not acceptable	Not acceptable	Not acceptable; soil must be rough enough for wind and rain to cover seeds
Seeding Depth	Variable and controlled	Variable; somewhat less controlled	Lays on top of the soil	No direct control; depends on soil	No direct control	No direct control
Seed Size	Variable if drills can be adjusted	Variable if hand-held machines can be adjusted	Small seed	Variable	Variable	Variable
Season	Limited by moisture	Limited by moisture	Limited by low expected mois-	Less limited	Less limited	Less limited
Precipitation	Slightly critical	Slightly critical	Very critical; more success when annual precip. exceeds 12-14 inches	Very critical	Very critical	Very critical
Soil Texture	Not critical	Not critical	Critical	Critical	Critical	Critical
Seed Distribution	Uniform	Uniform if person is well trained; seeds can be precisely placed	Less uniform	Less uniform	Not uniform but can be specific to one area	Not uniform
Mulching	Separate treatment	Separate	Same treatment possible but not advised	Separate	Separate	Separate
Cost	Medium	Depends on how many people needed	High	Low	Depends on number of crews needed	Low if surface area to be covered is extensive
Equipment	Special in some cases	Some hand-held equipment available	Scarce	Available	Some hand-held equipment available	Various types available; can be contracted out

Table 7. *(Continued)*

Characteristics	Drilling		Broadcasting			
	Machine	Hand	Hydroseeding	Other Machines	Hand	Aerial
Seed Rate	Less than broadcasting; drastically disturbed sites such as spoils require much heavier seeding rates than do sites where topsoil and some plant cover are intact. Examples: 10-15 lb/acre drilled on north-facing gentle slopes with small grass seed; 25-30 lb/acre if species seed is large; 40-45 lb/acre if conditions are severe, such as south-facing steep slopes	Same as machine drilling	More; as much as double the drilling rate	More	More	More; 1/3 more than drilling
Trash in Seeds	Must be cleaned from seeds	Must be cleaned from seeds	Cleaning not critical	Cleaning not critical	Cleaning not critical	Cleaning not critical
Time required/acre to seed	Middle range	High range	Low range	Low range	High range	Lowest

the front rollers. Rear rollers split the rows, plant the seeds, and compact soil around them to insure optimum germination. This seeder, designed for planting grasses and legumes, is capable of planting in rough terrain as long as it can be operated safely. It can also be used for covering seed that has been broadcast.

• **Rangeland drill** (fig. 28). This single-disk, deep-furrow drill with a high clearance has the advantage of being able to plant to greater depths in low precipitation areas. It is useful on clay loam soils that have been previously tilled. Its weakness is that it cannot readily handle trashy seed. This drill can accommodate rough terrain.

• **Steep-slope seeder** (fig. 29). This planter can be considered a combination drill and broadcaster. It is attached to the end of a hydraulic crane and extendable boom, and thus can plant seeds on very steep slopes, such as road fills and cuts. The seeder's teeth rough up the surface, the seed is broadcast, and drags cover the seed.

• **Nesbitt single or double disk drill with depth bands.** This drill is useful on gentle slopes in sandy or sandy loam soils.

• **Noble drill.** This drill is adapted to compacted, rocky, or gravelly soils.

Broadcasting:

• **Centrifugal-type broadcaster.** Also called end gate seeder, this broadcaster provides an economical method of seeding most varieties of seeds as well as applying granular and pelleted fertilizers. Centrifugal-type broadcasters generally have an effective spreading width of about 20-40 ft, depending on the physical characteristics of the seed. Hoppers are available that hold from 75-2,000 lb of seed or fertilizer.

• **Field distributor.** Also called full-width feed broadcaster, this machine consists of a seed box with metering devices along its full width. It does not have furrow openers or seed covers. Separate field operations are required to prepare the seedbed and cover the seed.

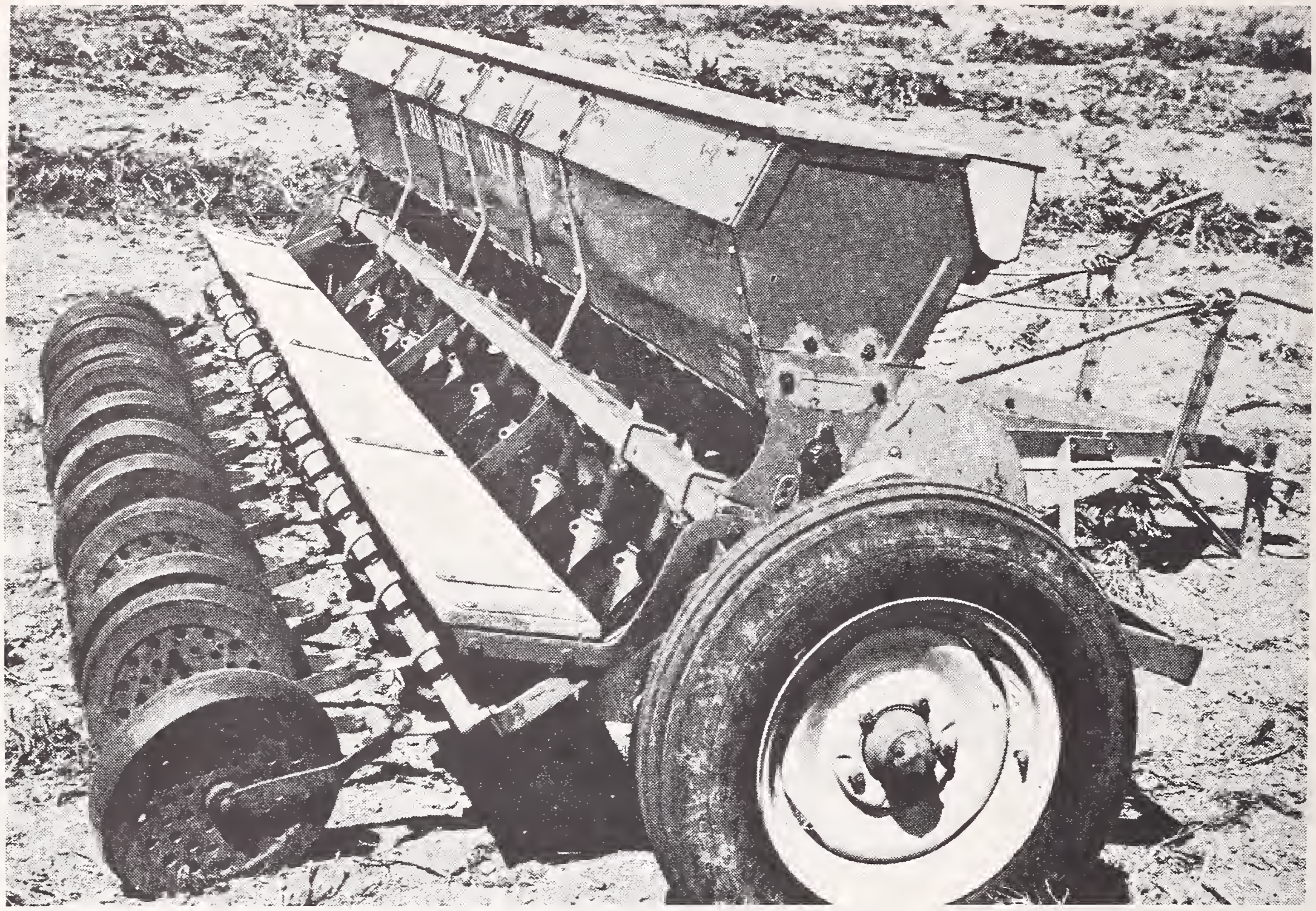

Figure 26. Packer wheels compact soil after drilling. (Utah Div. of Wildlife Resources)

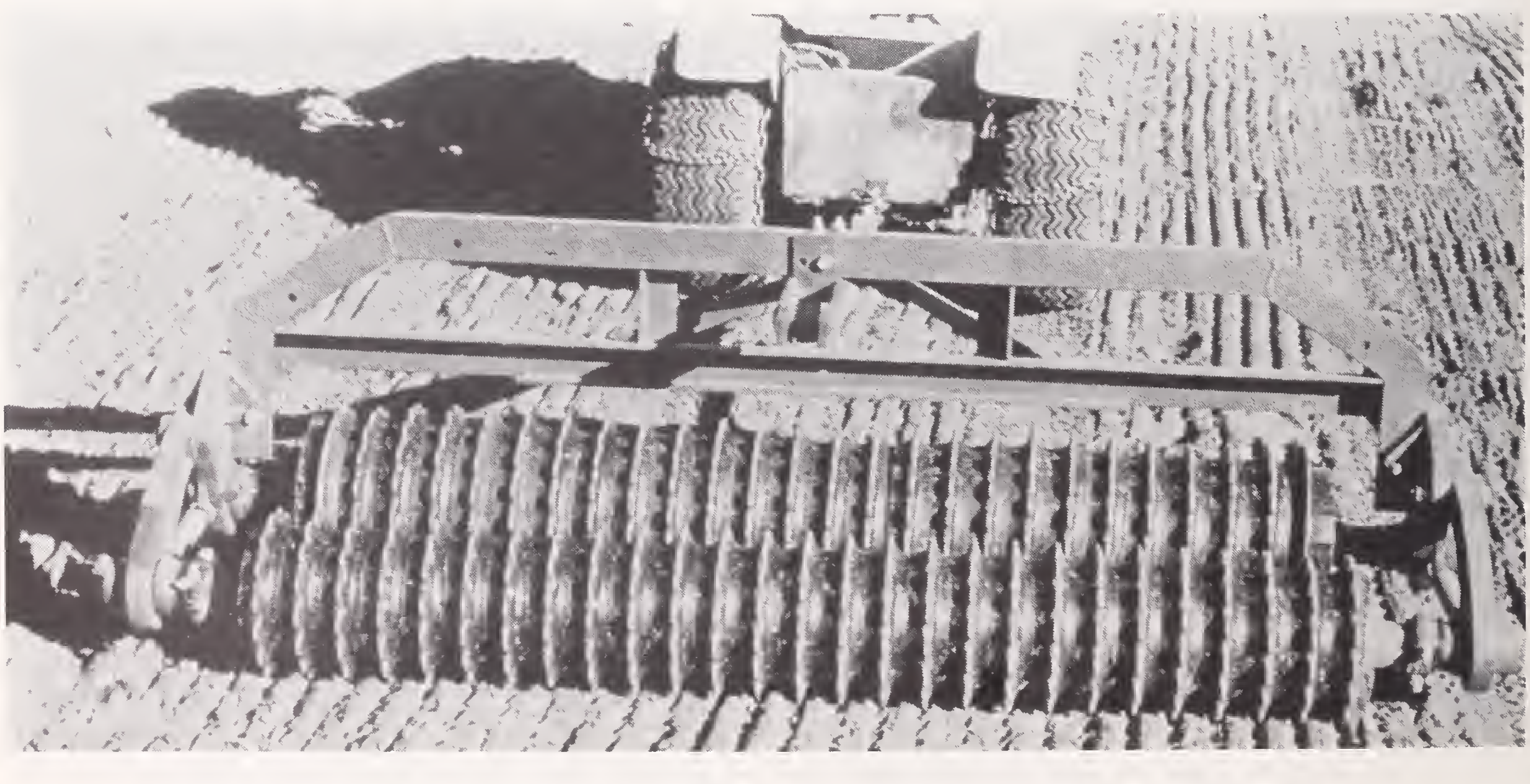

Figure 27. The seeder-cultipacker has been quite successful in mineland revegetation work.

• Fan or airblast seeder. This seeder can be pulled by a machine or is also available as a small, portable, hand-held version called the cyclone seeder.

• Hydroseeder (fig. 30). This machine applies seed by means of a high-pressure stream of water. The seed must be covered with soil or mulch in a separate operation to insure germination and establishment. This can be done by harrowing, disking, or using a small sheepsfoot roller. The same machine can apply mulch. If seed is applied with a mulch, the seed need not be covered with soil because the water/mulch mixture will act as a soil covering. Some research indicates, however, that this approach is not always successful because the mulch may prevent the seed from coming in contact with the soil.

Aerial seeders:

Aerial seeding, which is simply another way of broadcasting, is advantageous where the terrain is too rough to use land-going equipment. Often, these sites can be roughed up, for example by use of a chain (fig. 31), but not tilled enough to allow a drill to go over the site. Aerial seeding also provides maneuverability among sites, and it can be used in situations where the vegetation specialist wants to introduce some additional species into the area without disturbing the vegetation currently growing on the site.

Both fixed-wing and helicopter craft can be used for aerial seeding (fig. 32 and 33). The aircraft should be equipped with a positive, power-driven, seed-metering device. An adjustable opening, which allows the seed to drop out of the hopper by gravity, is not acceptable when a mixture of various seed sizes and weights is used.

Aerial seeding operations are normally contracted for. If the contract is based on an hourly

Figure 29. The steep-slope seeder is considered a combination drill and broadcaster.

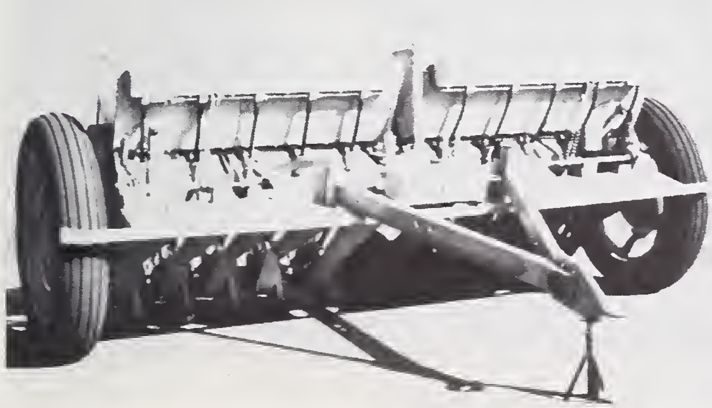

Figure 28. Rangeland drill, front view.

Figure 30. Hydroseeding is a type of broadcasting.

rate, it is recommended that the seed and all plans be ready before the aircraft arrives.

A crew should be on hand to guide the pilot in making overlapping passes. The operation should be delayed if the wind is too strong to get even seed distribution.

PLANTING OTHER STOCK

How is container grown stock planted?

In most cases, these seedlings should be planted by hand. Various hand-held planting tools have been developed, and limited success has been achieved using the equipment built to plant bare-root stock. Because sprigs and rhizomes are usually cultivated as tubelings, they should be planted in the same manner as other container-grown stock.

Discussion:

Machine planting will be efficient only if there is a large number of plants that can be placed in long, continuous rows, the terrain is suitable, and the machinery will not destroy the site preparation design.

Hand methods are mandatory when site preparation includes surface shaping treatments that would be damaged by subsequent machine operations. For instance, contour furrowing, gouging, and land imprinting are examples of site preparation that can be damaged by machines once these operations have been done. In addition, use hand methods when the terrain is extremely steep, or the spoil material is so rocky that proper machine planting would be difficult. When plants are to be set in groups or clumps, or when complex mixed plantings of several species are made, hand planting is necessary.

The following procedure is recommended for planting container-grown stock: Handle the stock prior to planting as described in chapter 3. When ready to plant, make a hole with a mattock, an auger, or a dibble punch (fig. 34). Judge the depth of the hole needed by looking at the size of the root system and depth of the plant container. Remove the plant from the container. Plant the container-grown seedling carefully, keeping the root plug intact, and firm the soil around the plant to eliminate air space.

How is bare-root stock planted?

Bare-root stock must be properly placed in

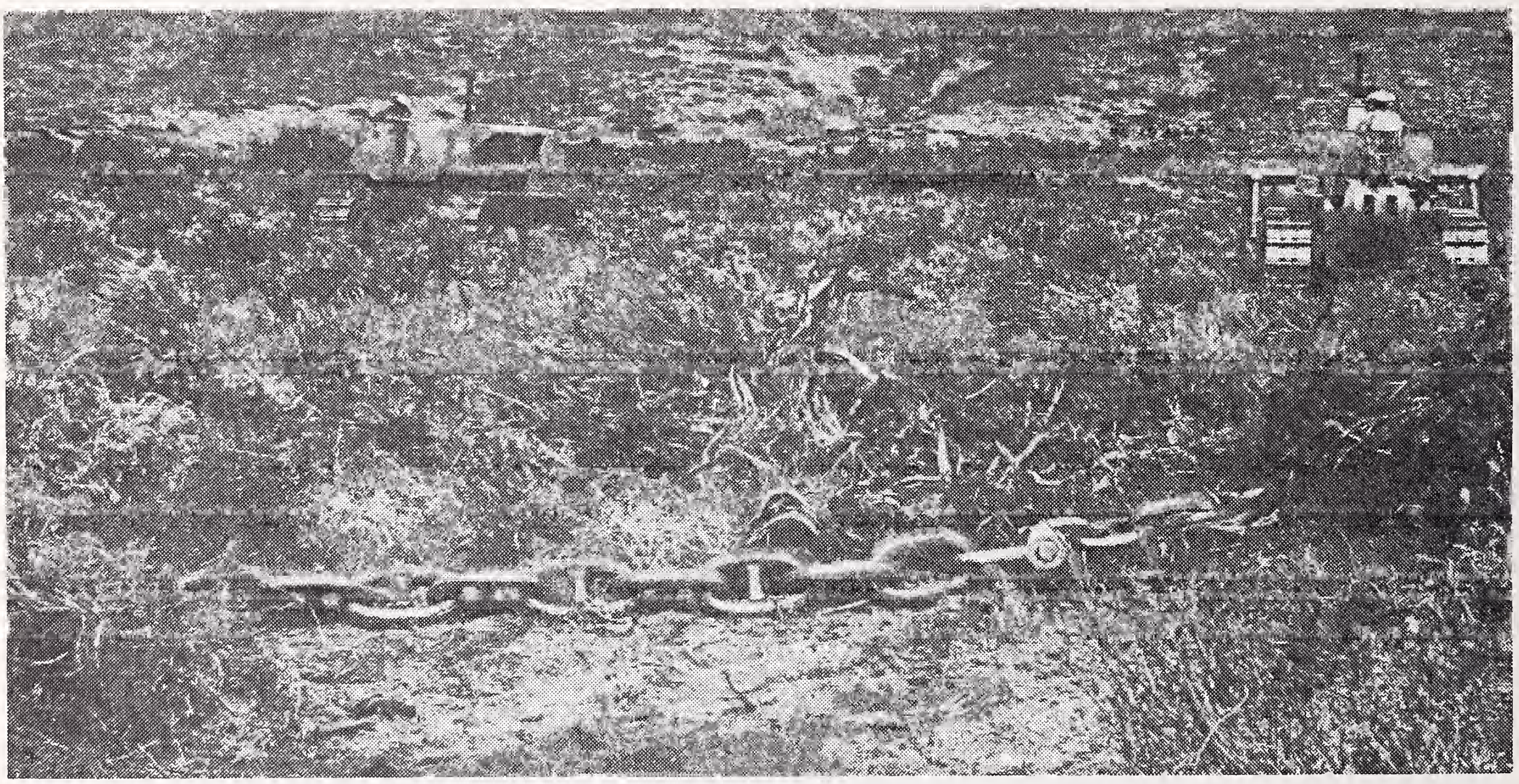

Figure 31. Anchor chaining is an adequate method for covering seed when tillage is extremely difficult. (Utah Div. of Wildlife Resources)

such a way to insure that the roots are well distributed, and firmly in contact with the soil to eliminate air pockets.

Discussion:

Prior to planting, the bare-root stock must be adequately cared for as described in chapter 3. Generally, spacing of the bare-root stock ought not to be less than 1-1/2 times the diameter of the mature plant. Do not expect greater plant densities on revegetated sites than occur on undisturbed sites.

When planting where risk of failure is high, current research recommends cross-wind furrowing and mulching to conserve moisture and trickle irrigation systems to provide supplemental moisture for one or two growing seasons. (For more on cultural treatments, such as irrigation, see chapter 6.)

How are cuttings planted?

Cuttings can be planted either rooted or unrooted when a favorable period of soil moisture exists.

Discussion:

When the cuttings are not rooted, they should be put in the ground only when a favorable period of soil moisture and temperature is expected for at least 30-45 days. Plant cuttings before they have broken dormancy and with a

Figure 32. Fixed-wing aircraft can seed rough areas if rainfall is adequate for seed germination. (Utah Div. of Wildlife Resources)

minimum amount of top exposed — less than 2 inches of a 1-ft-long cutting.

When the cuttings have been previously rooted in a greenhouse, plant them like container-grown stock.

Trees with trunk diameters of 1-1/2 inches or less can be planted like cuttings. Pack the soil closely around the cuttings so that there is good contact with the soil and no air space. Tree cuttings are recommended whenever the species adapts to cutting (willows and poplars, for example) and when there is enough moisture for them to become established. Cuttings as long as 4 ft can be planted. Cuttings such as these have been successfully established along streambanks to aid in water erosion control. Even if they are washed away by flooding, they will often continue to sprout on the bank. Tree cuttings can also be planted earlier in the year than other kinds of stock.

How are wildings and plugs planted?

These kinds of plant stock can either be directly transplanted from their natural habitat to the mine site, or, if they are nurtured in the greenhouse, they can be planted the same as container-grown stock.

Discussion:

When plugs are dug from native vegetation, they can be planted on the site using a shovel. Pack the soil tightly around the roots to eliminate air space. Nursery grown plugs and wildings can be planted in a similar fashion; however, a planting bar or dibble is recommended over a shovel.

How can trees be planted?

Planting seedlings has been covered earlier in

Figure 33. Helicopters are ideal for seeding irregular areas.

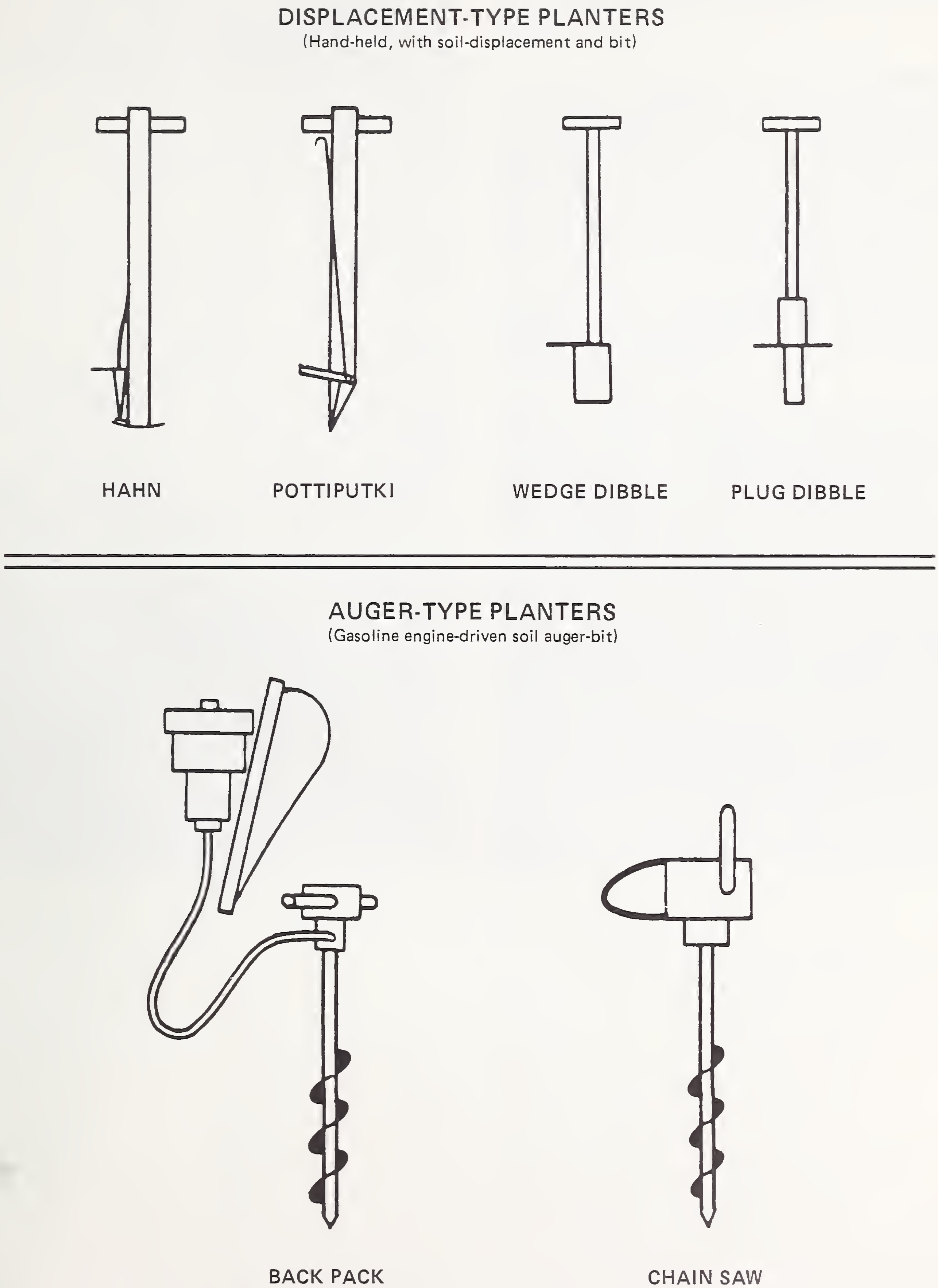

Figure 34. Hand planters for containerized seedlings.

this chapter. Clumps of trees can be transplanted using a front-end loader or a tree spade.

Discussion:

The front-end loader is efficient in digging up and moving pads of shrubs or trees, such as aspen. The pads must be replanted in an upright position, and guy wires may be necessary to anchor the trees. Because these trees will attract wildlife, it may be necessary to fence them until they are well established.

Tree spades have been developed for replanting small- to medium-sized trees. The spade mechanically digs, balls, transports, and replants trees and is available in different sizes. It is powered by its own gasoline engine, and the four digging blades are hydraulically operated. The largest of the spades will handle trees that are about 5-6 inches in diameter and will take a ball that is about 66 inches in diameter on the surface. Shrubs have also been successfully transplanted with the tree spade.

The spade can be towed with a 3/4-ton, 4-wheel drive pickup, which also carries a water tank to supply water to the tree spade lubrication system. A complementary trailer has been developed that will carry eight tree transplants. When using the tree spade, it is desirable to dig a hole that is larger than the size of the tree ball so that a small depression will be left after the tree is put in. This depression will catch available moisture.

A disadvantage of the tree spade is that its use is limited to slopes of 15 percent or less because the digging platform must remain level to insure that the tree is planted with its trunk vertical. Also, some trees having extremely long taproots cannot be transplanted successfully with the tree spade.

MIXED PLANTING

What are the general principles of mixed seeding?

When different sizes of seed are planted together, choose equipment that is adapted to mixed seeding and determine seeding rates based on seed size, purity, handling, and mixing capabilities.

Discussion:

Broadcast seeding accommodates different sizes and shapes of seeds and is useful if the seeds are covered in a subsequent operation. The Thimble Seeder and Hansen Seeder are two specific machines adapted to mixed-seed planting.

Some drills can also be used. For example, the rangeland drill, on which two seed boxes are attached, allows two seed sizes to be planted simultaneously, one seed type through each box. If a mix of seeds is drilled, it must be cleaned of trash to allow the seed to go through the drills. Proper seeding rates can be attained by adding carriers, such as rice hulls, with the seeds to dilute or help regulate distribution of seed.

Because mixed seeds may have different germination rates and periods of emergence, competition can be a problem. One way to minimize competition is to drill individual plant species in alternate rows. Spot seeding or site-specific seeding can also be done—but this technique usually requires hand-planting. Interseeders can be used to scalp away the topsoil where there is weed competition and then desired species can be seeded in the furrows made by the interseeder. Or, the vegetation specialist can drill grass seed in a site during one operation, and then come back later and interseed with other species.

What are the considerations of mixing seeds and transplant stock?

There are many advantages to mixing seeds and transplant stock, but a variety of planting methods may have to be used to minimize competition.

Discussion:

Advantages to this planting technique include:

- Irregular tracts with different site capabilities can be revegetated with clusters of plants.
- Highly erodible sites, needing a fast developing cover, can be planted with transplant stock, and remaining areas can be seeded.
- Sites with poor seedbed conditions, such as rocky surfaces, crusting soils, or toxic soils, require individual treatment, and this can be provided by mixed planting.
- If the species desired are in short supply, mixed planting maximizes the use of these species.
- Species to be mixed can be chosen to promote desired successional changes.

A recommended method of mixing seeds and transplant stock is to drill the seed, allow the plants to emerge, scalp them in certain spots, and then transplant into the scalps those species that are more adaptable to container, bare-root, or cutting cultivation. If competition from the seeded species is a problem, the grasses and transplants can be planted in alternate rows or in separate clumps.

Additional Information:

For more information on equipment for rehabilitation, refer to "Equipment for Reclaiming Strip-Mined Land," by Darrell Brown, USDA Forest Service, Equipment Development Center, Fort Missoula, Mont. Feb. 1977. No. 7728-2503, 58 p., illus.

For more information on planting methods, refer to:

"Plant Materials for Use on Surface Mined Lands in Arid and Semi-Arid Regions," USDA Handbook. Soil Conservation Service (SCS-TP 157), Lincoln, Neb. (in press).

"Restoring Big-Game Range in Utah," by A. Perry Plummer, Donald R. Christensen, and Stephen B. Monsen, Publication No. 68-3, Utah Division of Fish and Game, Ephraim, Utah. 1968.

Chapter 6
CULTURAL TREATMENTS

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Rehabilitation, by its definition, is a process initiated by man. The same definition holds true for cultural treatments. These treatments are often essential to establish a permanent plant cover and thus to assure that the rehabilitation process will succeed. The vegetation specialist plays a key role in advising the land manager or mine operator on the types of cultural treatments that should be used on a particular site. This chapter will discuss some of the principles the vegetation specialist should consider regarding cultural treatments. Treatments covered include irrigation, mulches, fertilizer, water harvesting, companion crops, and cultivation.

IRRIGATION

Irrigation, long used by western farmers, is also an important activity to consider when rehabilitating mined land.

When should irrigation be used?

Because irrigation is costly, it should be used as a temporary measure to enhance germination, help establish cover, and build up moisture in the soil. In some cases, irrigation can be used to aid in leaching salts from the soil. The vegetation specialist should keep in mind, however, that the plant community must eventually survive under natural conditions.

Discussion:

In general, irrigation should be considered when:

- The mined area will receive less than 10 inches of precipitation annually.
- Acquired water rights allow the use of irrigation water by the reclamation manager.
- Acquired water rights are sufficient.
- The water requirements of the plants dictate that irrigation be used.
- An area receives more than 10 inches of annual precipitation, and irrigation water is relatively inexpensive and available, such as from runoff or natural ponding. State water rights may affect the possibility of using these water supplies.

Leaching will be minimal or absent in the arid lands of the Southwest where spoils may be irrigated with an average of 12 inches of water per year.

How often and how much irrigation is necessary?

The amount and frequency of irrigation depends on the amount and intensity of natural precipitation, mine spoil make-up, density of plant cover desired, the species' water requirements, other applied cultural practices, and the availability of labor and funds.

Discussion:

- **Natural precipitation and mine spoil make-up.** It is known that the amount of rain absorbed by a soil depends on precipitation rate, infiltration rate, and water-retention capacity. If the precipitation rate is slower than infiltration, the soil will soak up all the precipitation up to its saturation point. If precipitation exceeds infiltration, surface runoff will occur.

It is also known that water readily infiltrates sandy soils, soils high in organic matter, and uncompacted soils. On the other hand, water does not readily infiltrate clay soils or soils low in organic matter. Sandy soils have less water-retention capacity; clay soils have greater water-retention capacity. These factors should be

balanced against one another to determine the optimum amounts, frequency, and rates of irrigation.

As one example, at the Navajo Coal Mine in northwestern New Mexico (grassland, elev. 5,200 ft, average annual precipitation 6 inches), the spoils are predominantly a clay type. Thus their water-retention capacity is high but problems occur with water infiltration rates. In this case, the spoils were classified as light, heavy, and medium, based on clay content. Heavy spoils had a clay content greater than 50 percent. Medium spoils were from 50-35 percent clay, and light spoils were below 35 percent. Watering regimes were established for each type of mine spoils as is shown in table 8. The table illustrates that the type of spoils greatly affects the rates of irrigation required to establish desired plants.

Information on optimum watering regimes for various kinds of mine spoils is not currently available in published form. The vegetation specialist should be aware that recommended rates on agricultural soils may not apply to mine spoils; however, because many spoils are a clay type, the information in table 8 should have wide applicability.

- **Density of plant cover desired.** Some ecologists have noted that it is inadvisable to try to attain a greater density of plant cover than that on adjacent undisturbed sites, because irrigation and other cultural treatments will be temporary. After they cease, the plant community must survive under natural conditions. It is difficult, however, to determine the plant density of an undisturbed area, since most regions of the West have been either overgrazed or disturbed in some way by man. Thus, other scientists claim that it is feasible to expect reclaimed lands to support and sustain greater plant densities. This problem is unresolved at present; however, regulations governing a particular mine site may set high density standards for plant cover.

- **Species' water requirements.** Certain warm season species—the gramas, blue stems, switchgrasses, for example—can be established with minimal watering. If these grasses are irrigated for a few days, they will germinate. A second moist period is needed 3 or 4 weeks after they emerge when secondary rooting is initiated. These roots will grow quickly—1/2 inch per day. So, by irrigating at the right time, certain grasses can be established that are normally difficult to root.

- **Labor requirements.** Note that in the case of the Navajo Mine, 12 inches of water were irrigated onto the spoils in the first year of revegetation, 2 inches in the second year, and none thereafter. In this operation, labor requirements and costs dictated that the irrigation period be no longer than this.

The reader is also referred to the section in this chapter on water harvesting, which discusses ways of taking advantage of natural precipitation, thus cutting down on man-hours and costs to irrigate using other water sources. Costs and labor requirements will be noted in the discussion of drip versus sprinkler irrigation systems.

What type of irrigation system should be used?

The two most frequently used irrigation methods for reclaiming mine sites are drip irri-

Table 8. — *Watering regimes on mine spoils, Navajo Mine, New Mexico*

Spoil type	Hours duration	Frequency	Total amount applied
Light clay content	8	Every other day	12 inches the first year; 2 inches the second year; none thereafter
Medium clay content	6	Every 6th day	12 inches the first year; 2 inches the second year; none thereafter
Heavy clay content	4	Every other day	12 inches the first year; 2 inches the second year; none thereafter

(System Used: Laterals set 40 ft apart, with sprinkler heads 40 ft on the laterals; pressure regulating valves aided in delivering about 1.8 gal/min—an application rate of 0.08 inch/hr)

gation (fig. 35) and sprinkler irrigation. Factors such as the need to minimize water evaporation, site conditions, labor requirements, and costs should be considered when choosing between the two. Table 9 outlines the advantages and disadvantages of these two systems.

MULCHES

In the reclamation process, a second vital cultural treatment is mulching. A mulch is defined as any nonliving material placed or left on or near the soil surface for the purpose of protecting it from erosion or protecting plants from heat, cold, or drought.

When discussing mulches in reclaiming mined lands, a number of considerations should be addressed.

Why use a mulch?

Most researchers agree that probably the most effective way to stabilize an area of land is to establish plant growth as quickly as possible on the soil surface. Mulching will protect the site until plants become established and will often shorten the time for establishing adequate plant growth—if it is used with other good management practices.

Discussion:

The reasons that a mulch can aid in establishing plant growth are that it will:

- Prevent erosion, both by water and wind.

Table 9. — *Advantages and disadvantages of drip and sprinkler irrigation systems*

Type of irrigation system	Advantages	Disadvantages	Comments
Drip irrigation	Uses 1/3 less water	If water contains high sediment level, it will clog the lines, unless well filtered	Also called trickle irrigation Plant densities will be less; this can be a disadvantage, but not always
	Evaporation is minimal	If water is high in salt, salt deposits can build up around the emitter openings	Adequate filtering system crucial
	Amounts of water can be placed directly where wanted	Needs more maintenance than a sprinkler to check filtering system	Quality of water (sediment, salinity) a factor
	Especially useful on steep slopes, under power lines (because it is safer), between buildings, on critical areas	Labor intensive Less easy to move Shorter life span than sprinkler system	Three types of emitters: spitter (puts out a spray); single (puts small amount in local place); and bi-wall (plastic tubing with pin-prick opening to emit water)
	Moves salts away from plant roots Well suited for woody plants	Higher costs than sprinkler	A portable drip system, using a 500-gal tank has been developed by the Rocky Mountain Station at Albuquerque
Sprinkler irrigation	Less filtering needed	More evaporation will occur	Choose between solid set or movable
	Less expensive than drip	Need larger water supply	High plant densities possible
	Less labor intensive	Frequency of application higher than drip	
	Longer life		
	Easier to move, more flexible		

Figure 35. Second growing season using drip irrigation system.

- Facilitate infiltration.
- Inhibit evaporation (which may also slow upward movement of salts through spoils and/or soils).
- Provide proper soil temperatures.
- Be compatible with plant development, improve germination conditions, protect seedlings.
- Possibly add desired seeds while acting as a mulch.
- Reinoculate micro-organisms into mined spoils.

Of course, no one mulch will meet all of these criteria; thus, the vegetation specialist should determine which attributes are most important in his situation and choose the mulch that most nearly satisfies his needs.

Mulches will accomplish the following:

Water erosion control.

- Dissipate kinetic energy of raindrops.
- Lessen structural destruction.
- Lessen splash erosion.
- Lessen surface sealing.
- Allow more infiltration, less runoff.
- Lessen rill and channel erosion.

In the Southwest, mulching is particularly valuable in protecting seeded areas from the high intensity, short duration storms that often occur in the first summer rains.

Wind erosion control.

- Protect aggregates physically.
- Decrease wind velocity at soil surface.
- Help keep soil moist.
- Lessen particle movement.

Water conservation.

- Allow more infiltration, lessen runoff, and reduce evaporation from the soil surface because of the physical cover.
- Restrict air movement and allow higher relative humidity at the soil surface, and thus reduce water diffusion from the soil air out into the atmospheric air.

Temperature control.

- Lower or raise temperature by absorbing or reflecting radiant energy.

Typically, dark colored mulches can help raise spring temperatures and speed up the germination rate, whereas light colored mulches can help lower summer temperatures, thus aiding areas where the soil surface can become too warm for optimum plant growth. It has also been found that in high elevation areas, mulches seem to reduce the problem of young seedlings being lifted out of the ground by frost heaving; this is probably because the mulch creates a heat trap.

In general, a mulch will decrease the range of fluctuation of temperatures.

> **Exception:** With regard to darker colored mulches, a problem can arise if the soil is warmed by a mulch, followed by premature germination and inadequate soil moisture. In these cases, the seedling may start growing, run out of moisture, and then die.

Weed control.
- Best for shrub plantings or row plantings.

Germination and plant development improvement.
- When broadcast seeding is used, best results are obtained by broadcasting the seed, covering with soil, then applying mulch.

What are some of the potential problems associated with mulches?

When considering mulches, a vegetation specialist should realize that mulches can sometimes cause problems including nutrient and waste immobilization, germination inhibitation, and the attraction of unwanted organisms. He should choose a mulch after consideration of these potential problems.

Discussion:

Three significant problems with mulches are the immobilization of nitrogen (N), phosphorous (P), and sulfur (S); germination inhibition; and the attraction of unwanted organisms.

Although not as much research has been done with phosphorus and sulfur, it is known that if an organic mulch has a carbon to nitrogen ratio of much greater than 25:1, it could potentially cause nitrogen deficiencies because the micro-organisms attacking that organic matter are much more efficient in using any inorganic nitrogen that is in the soil than are the plants. Thus, these micro-organisms tend to decrease the availability of inorganic nitrogen and leave a deficiency for a short time. Included among mulches that have a very high carbon to nitrogen ratio are straw (fig. 36) and wood waste materials. The same principle can be applied to P and S.

Mulches high in nitrogen could produce a high ammonium concentration around germinating seedlings that could be toxic. Some organic mulches have phytotoxic materials that can be toxic to seedlings in some circumstances. And, mulches can cause slow germination and plant growth due to lower temperatures or water immobilization.

A third problem concerns unwanted organisms: insects, fungi, diseases, rodents, and weeds. For example, excelsior can attract mice, which then eat the seeds or the seedlings as they come up.

How is a mulch selected for a particular site?

Three general items should be analyzed when choosing a mulch—the site, the mulch effectiveness, and the vegetation desired.

Figure 36. Straw is an effective and economical mulch, but may cause nitrogen deficiencies.

Discussion:

When assessing site characteristics, look at:

- Topography.
  - Percentage slope
  - Aspect (does the slope face north or south, east or west?)
  - Roughness
  - Micro-slope and macro-slope aspects

These factors will affect the ability of the mulch to adhere to the site; aspect may influence the color of the mulch chosen—i.e., to either absorb or reflect heat.

- Spoil properties.
  - Texture, depth
  - Structure, surface roughness
  - Organic matter, infiltration, permeability

These factors will indicate what characteristics the mulch must ameliorate on the site; mulch choice will be influenced by these factors.

- Precipitation characteristics.
  - Intensity of storms
  - Total precipitation during a given storm
  - Seasonal distribution of storms

In other words, will the mulch be washed away in heavy rains? Will the mulch prevent moisture from reaching the plant/spoil materials?

- Needs for special equipment and cost of application.

When assessing a mulch, look at:

- Physical characteristics.
  - Color (important in terms of temperature)
  - Density (some mulches of low density will float down a slope during a storm)
  - Roughness
  - Durability, tenacity—will it stay in place where you want it to; will it attach itself to the soil or other organic material that is there?
  - Availability, distance (affects costs)
- Chemical characteristics.
  - Toxicity and decomposibility
- Manner of application (affects labor requirements).
- Cost.

When assessing the types of vegetation being cultivated, consider their germination rates and percentages, rooting habits, and drought resistance capability.

What are the pros and cons of various kinds of mulches?

Each mulch has typical properties. Their pros and cons should be judged against costs, type of vegetation to be cultivated, and the site to be mulched. Table 10 lists some of the more commonly known mulches, and their advantages and disadvantages. Also see figures 37-43.

Additional Information:

For a summary of methods and costs of common erosion control practices, including mulches, see:

"Hydroseeding, Straw and Chemicals for Erosion Control," by B. L. Kay, Agronomy Progress Report No. 77, Agronomy and Range Science Dep., University of California at Davis, 14 p. June 1976.

FERTILIZATION

Although fertilizers alone are not a cure for nutrient-deficient soils and spoils, when they are used in combination with proper spoil grading, topsoiling, planting methods, selection of species, mulching, and moisture, fertilizers will greatly enhance the chance of revegetation success. Fertilizers add nutrients to the soil, which: (1) permit plant establishment; (2) speed

Figure 37. Hydromulching a steep slope.

Figures 38-43. Various kinds of mulches used in revegetation work. (Burns Sabey, Colorado State University)

Figure 38. Gravel applied at 135 tons/acre.

Figure 39. Woodchip mulch.

Figure 40. Excelsior blanket.

Figure 41. Straw jute.

Figure 42. Straw applied at 2 tons/acre.

Figure 43. Cotton netting used to hold mulch in place.

Table 10. — *Advantages and disadvantages of commonly used mulches*

Type of Mulch	Advantages	Disadvantages	Comments
Crop residues: Straw or hay	Generally most economical Usually satisfactory under many circumstances	Weed seeds usually present; even hay seeds may be considered a weed on a particular site Straw may "wick-out" moisture from soils in very dry conditions, thus resulting in poor germination and seedling establishment	Anchor mulch, especially on slopes by crimping, or using plastic meshes, jute, chemical tackifiers Long-stemmed best, especially for crimping Uniform application important Generally, 2 tons/acre adequate In Utah, it was found that rotovating mulch 6-8 inches into soil increased grass seedling survival Can be spread with modified farm manure spreader
Native grasses; prairie hay	Adds desirable native species seeds to area and mulches at same time	May harvest weeds along with native species	
Wood residues: sawdust, woodchips, bark, shavings	Protects surface Adds organic matter No weed seeds More fire resistant than straw Long lasting Easy to apply Chips resistant to wind movement	Shavings and sawdust blow Nitrogen deficiency Packing may occur resulting in less aeration May float on running water May prevent precipitation from reaching spoil	Chips: 2 tons/acre usually adequate; chip size, 1/2 inch to 1/50 inch
Plastic film	Excellent vapor barrier Good weed control Light-colored, perforated, found effective in New Mexico: soil temperature in summer 18° F lower than in soil with no mulch	Labor intensive High cost	Information on temperature effect varies Color is important because of reflection, absorption
Fiber tackifiers and soil binders	SBR Styrenebutadiene and SS Super Slurper have been found to be very absorbent and thus help provide water	Quite expensive Must be applied correctly in order to have maximum effectiveness With SBR Styrenebutadiene and SS Super Slurper premature germination may occur In high wind areas, it can solidify, break into pieces and blow away	Typically added into water carriers; can also be added with seed slurries 500-1,000 lb. of solids/acre usually sufficient, dilution rates of 5:1-7:1 optimum
Rocks, gravel, pebbles	Effective at specific sites Are permanent—do not disintegrate	Smaller than 1/12 inch in diameter not good for wind erosion	Choose sizes greater than 1/12 inch in diameter Must nearly cover entire ground surface—1-2 inch thick is effective control (135 tons/acre = about 1 inch depth)
Mixtures	Add micro-organisms to soil over short and long term (Ex.: straw and bark)		

Table 10. *(Continued)*

Type of Mulch	Advantages	Disadvantages	Comments
Hydraulic mulching	Labor costs low Typical green color allows operator to get uniform distribution Hydromulching and hydroseeding can be done at the same time, if it is impossible to do the two operations separately Wood cellulose fiber mixed with seed and fertilizer can be sprayed on steep slopes	Of little value unless it adheres to the soil surface and remains intact during rainstorms, wind Hydromulch with fiber improves germination, but does not improve production When hydromulch and hydroseeding are done together, seeds may not have adequate soil contact	Application rate of 1,500 lb/acre appears adequate for most situations; may need more for quite steep slopes May need to add N to hydromulch to compensate for C:N ratio of mulch chosen Always put some seed in mulch Hydroseeding and hydromulching together should be reserved for special cases when moisture is sufficient to keep the seed moist for 2-3 weeks after seeding
Fabric or mats: jute, excelsior, woven, paper, plastics, nets	Especially useful on steep slopes Nets good in high wind areas	Expensive: 4-5 times more than tacked straw High labor input for anchoring Not effective on rough surfaces or rocky areas Erosion from beneath may be a problem	Used only on limited critical areas because of cost
Manure and sewage sludge	Can protect soil surface and adds nutrients, such as N, P, K, S	When used alone, it becomes wet, then dry, can lose much of N through volatilization of ammonia	Needs 5, 10, 15 tons/acre in order to protect soil On bentonite spoils, a grass establishment study showed that an application of wood chips as mulch and sewage sludge as N supplier was more effective than a high application (400 parts per million) of inorganic N
Asphalt	Rapid-curing asphalt keeps straw and other materials in place Slow-curing asphalt allows for growth of seedlings before it cures Coats surface, remains intact 4-10 weeks A stabilizer for straw Nonporous, and conserves water underneath it Some plants react positively to it	Nonporous, thus causes surface water to run off Some plants react negatively to it	Make decision based on type of asphalt (slow, medium, rapid curing) desired Make decision based on reaction to asphalt by plant species desired 1,200 gal/acre an average application Typically, heated and spread by spraying Apply from top of slope down, so impermeable caps are built on clods of soil down the slope, leaving sides free for seedlings to come out of and to absorb water
Resin emulsion in water	More porous than asphalt Insoluble in water Resistant to weathering		600 gal/acre good against wind erosion Often considered superior to asphalt
Latex emulsion	Resistant to erosion	Limits water penetration Some studies indicate it is less effective than some other mulches	

up plant growth; and (3) maintain plant productivity. On mine spoils, fertilizer will speed up the production of biomass, which will provide long-term nutrients to the plants.

What criteria determine if a fertilizer should be used?

Several factors influence the decision to use fertilizer: (1) the nutrient needs of the plant species to be planted; (2) known nutrient deficiencies in the soil/spoil; (3) effect of fertilizers on soils/spoils; (4) necessity of refertilization; (5) cost; and (6) available soil water.

Discussion:

Some plant species have less nutrient needs than others and thus may not require fertilizers. Plant physiologists should be able to advise on the nutrient needs of the desired plant species.

Soil/spoil nutrient deficiencies are determined by field and lab soils tests. Work with the soils specialist to determine this factor.

Effects of fertilization on soils/spoils are best determined by running field plot studies.

What nutrients are most commonly lacking in spoils?

Mineral deficiencies on disturbed lands are dominated by nitrogen (N) and phosphorus (P) deficiencies. The vegetation specialist should be aware of the characteristics of these deficiencies, and the methods used to detect them. It should also be recognized that organic carbon content is generally low in spoils and may be biologically inert.

Discussion:

Nitrogen. When looking at the possibility of a nitrogen deficiency consider:

- An N deficiency is often a limiting factor in plant productivity, rather than seedling establishment.
- Subsoils and geological materials will probably be extremely nitrogen deficient; topsoils will usually contain adequate nitrogen.

> **Exception:** Some shales, the cretaceous and tertiary shales, for example, are fairly high in nitrogen; however, it is thought that after several years of plant growth on these shales, the N may be used up and the plant system may become N deficient.

- Nitrogen soil tests are of limited value in detecting N deficiencies on geological materials and on subsoils; however, they are recommended as a good starting point. When in doubt, strip N on field test plots at various rates to determine response to N fertilization.
- There are natural N inputs from precipitation onto disturbed lands (2-3 lb/acre/yr in desert areas; 4-5 lb/acre/yr in the mountains; 6-10 lb/acre/yr on the plains). But this process adds only a relatively small amount of N per year.
- Indications of N deficiencies: Sickly yellowish-green color; chlorotic foliage; distinctly slow and dwarfed growth; drying up of or "firing" of leaves, which starts at the bottom of the plant and proceeds upward. These, however, are only indications; other factors may be at work. Soil and plant-tissue tests may be needed to confirm observations.

Phosphorus. When looking at phosphorus deficiencies consider:

- P deficiencies limit or prevent seedling establishment; this occurs to such an extent that plant failure is often attributed to lack of moisture in the soil, when, in fact, the soil is so P deficient that the plants do not grow enough to extend their roots down to the available moisture supply.
- P soil tests are usually reliable for detecting phosphorus deficiencies.
- Other indications of P deficiencies: purplish leaves, stems, and branches; slow growth and maturity; small slender stalk or lack of stooling; low yields of seed.
- P deficiencies are most readily seen in seedlings.
- Losses of P by leaching or volatilization are usually considered to be small.

What steps are taken to correct a P deficiency?

Add P in the form of P_2O_5 (phosphorus pentoxide), using quantities based on the extent of the deficiency and following recommended procedures for use of the fertilizer. The following recommendations can be used until on-site experience or research shows that other methods are more appropriate.

Discussion:

- Use relatively high amounts of P_2O_5 on drastically disturbed lands that test deficient in

plant available P; 100 lb/acre P_2O_5 on coarse-textured soils and 200 lb/acre on fine-textured clay soils have been recommended.

• Consider using commonly available P sources. Examples: (1) Triple Superphosphate (0-46-0 = 46 percent P_2O_5). Superphosphates may range from 42-53 percent P_2O_5; the notation 0-46-0 means that in a 100-lb bag of fertilizer, there are 0 lb of N, 46 lb of P_2O_5, and 0 lb of K (potassium) (also see fig. 44); (2) 11-48-0 (ammonium phosphate); (3) 16-20-0 (ammonium phosphate); (4) 21-53-0 (diammonium phosphate); (5) sewage sludge; (6) manure. When using sewage sludge or manure to meet N requirements, enough fertilizer will probably be added to also meet phosphate requirements.

• Amounts applied are related to the percentage P in the fertilizer; i.e., to apply 100 lb/acre of P_2O_5 as 0-46-0 requires 217 lb of 0-46-0 fertilizer.

• Do not use less soluble P sources on neutral and calcareous soils. (Superphosphates and ammonium phosphates are soluble P sources.)

• Mix phosphate into the soil before seeding for best results. Especially in the fine-textured soils of arid and semi-arid regions, it is important to get phosphate into the soil for the seedlings to grow into.

• Phosphorus fertilization has a long-lasting effect, and thus the soil/spoil may need only one P application.

What steps are taken to correct an N deficiency?

Many sources of N are available; soil tests and on-site experience will help the vegetation specialist recommend the best sources for specific situations.

Discussion:

• Whenever possible, save dark topsoil because it usually contains adequate N for plant systems.

• When N is deficient, apply 40-50 lb of N/acre to disturbed sites. When 2 tons of straw per acre are used as mulch and crimped into the soil, 50-60 lb/acre of N may be required in addition to the above N. With sufficient moisture, 80 lb of N/acre (500 lb of 16-16-16) have been added successfully.

• Sources of N fertilizer include (1) ammonium nitrate, 33-0-0 (most commonly available, usually the least expensive); (2) ammonium sulfate; (3) urea, 43-0-0 (a highly concentrated N source, that can be subject to volatilization loss when broadcast on the surface; costs are comparable to 33-0-0); (4) ammonium phosphates, 16-20-0, 11-48-0, 21-53-0; (5) sewage sludge; (6) manure. (Sludge and manure are alternative N sources where available and when transportation costs can be afforded.)

• Amounts applied are related to percentage of N in fertilizer; i.e., to apply 50 lb N/acre would require 150 lb N/acre as 33-0-0 or 238 lb of N fertilizer as 21-0-0.

• In areas where late fall seeding is done, the optimum time to apply N is after germination in the spring; in the spring seeding, N can be applied at the time of seeding, but keep N from contact with the seed.

• Nitrogen is quite water soluble, so it can be surface applied; it is best to apply N before expected moisture.

• In some situations where annual weeds may offer stiff competition to perennial establishment, N fertilization may be delayed until the

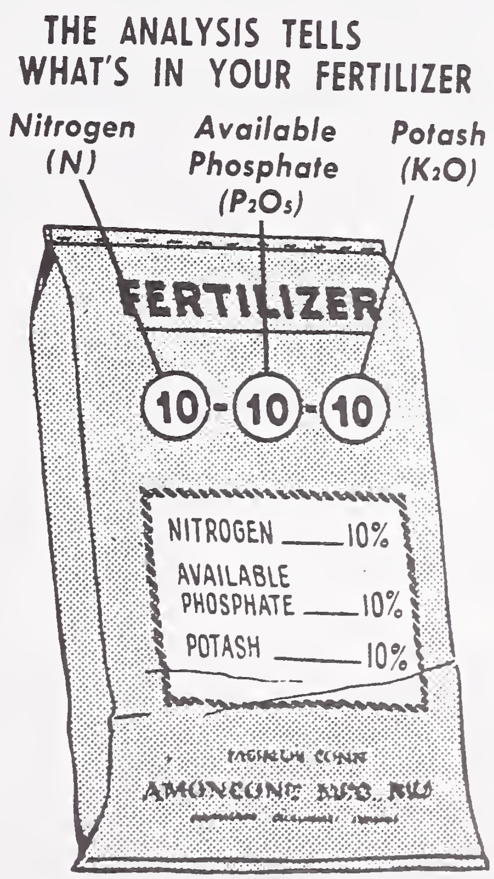

Figure 44. Fertilizer labeling gives nutrient content. (The Fertilizer Institute)

second growing season. Once perennials have been established, annual weeds usually cannot compete.

• Nitrogen fertilization effect is short term; repeated applications may be necessary. Visual observations are usually the best guide to N refertilization needs although soil tests are another indication. (Also see chapter 7.)

What kind of maintenance fertilization will be needed?

Phosphorus can be applied once (this should be sufficient to start P cycling); however, N may have to be added every 2 or 3 years on certain N-deficient soils.

Discussion:

• Certain sites may need substantial amounts—up to 500-700 lb/acre of N. This may entail adding 30-40 lb/acre of N every 2 or 3 years for 10 or even 20 years. Expense and labor availability are concerns here. Such sites include those with coarse-textured soils, subsoils, geologic materials, or high precipitation.

• Alternatives to applying N: (1) Replace topsoil whenever possible; (2) choose N-fixing plant species, although in drier areas, few of these species are available; (3) plant less N-demanding species (such as rabbitbrush, sagebrush, lodgepole pine).

• Consider maintenance N when foliage is a light green color and/or there is a substantial reduction in ground cover.

> Exception: Consider limiting N maintenance if goal is to encourage invasion onto site of less N-demanding species.

• When in doubt, apply N to field test plots; if site receives moisture, a response should be seen in about 10 days.

What other nutrients may be lacking in the soils/spoils?

Nutrients are divided into macronutrients, which plants need in large quantities, and micronutrients, which plants need in small quantities. Phosphorus and nitrogen are macronutrients. Other macronutrients are potassium, calcium, magnesium, and sulfur. Soil tests will indicate if these are lacking in the soil. Among micronutrients are boron, manganese, copper, zinc, iron molybdenum, and chlorine.

Discussion:

Soil tests, plant-tissue tests, observable deficiency symptoms in plants, greenhouse tests, and field test plots are all methods used to discover nutrient deficiencies. The effects of micronutrients on vegetation establishment have not been fully evaluated. In addition, keep in mind that the acidity or alkalinity of the soil will affect the ability of the plant to take nutrients into its system.

> Exception: Toxic levels of nutrients are also possible; a familiar example in the West is saline soil, which bears too many mineral salts, including nutrients like calcium and magnesium (a Ca/Mg ratio exceeding 1:10 may present problems). Again, soil tests will detect this problem, although the effects of toxic amounts of nutrients, especially micronutrients, are not fully known.

How is fertilizer applied?

Some suggestions for N and P application have already been given. In general, application methods depend on the plants, soil, climate, date and rate of application, kinds of fertilizer, and equipment available. The goal: To get the proper amount of fertilizer in the soil where it will do the most good.

Discussion:

Broadcasting, banding along the row, deep drilling, plowing, drilling with seed, foliar application, side dressing, bedding, starter solutions, top dressing, and irrigation are all methods of applying fertilizer.

Are fertilizers dangerous to humans?

They can be; consult publications available from the Fertilizer Institute, 1015 18th Street N.W., Washington, D.C., covering safe handling of various kinds of fertilizers. District offices of the Occupational Safety and Health Administration (OSHA) also have information for safe handling of fertilizers.

Additional Information:

For more information on the uses of ferti-

lizers in specific situations, consult local Soil Conservation Service offices.

Also consult:

"Soil Fertility and Fertilizers," by Samuel L. Tisdal and Werner L. Nelson, MacMillan Publishers, N.Y. Collier MacMillan Publishers, London, 1975. 694 p.

"Soil Testing and Plant Analysis," by Leo M. Walsh and James D. Beaton (ed), Soil Science Soc. of Amer., Madison, Wisc. 1973. 491 p.

"Western Fertilizer Handbook," Soil Improvement Committee, Calif. Fertilizer Assn., Interstate Printers and Publishers, Inc., Danville, Ill. 1975. 250 p.

WATER HARVESTING

Water harvesting is the practice of using the landscape to collect and accumulate runoff water and concentrate that moisture in a plant-growing zone. First practiced by ancient man, it continues to have application today in arid regions of the world. In nature, the principle of water harvesting is demonstrated by greater plant densities near gullies and depressions in arid lands.

When should water harvesting be used?

Water harvesting is appropriate in areas that receive less than 15 inches of precipitation annually; it is also useful in any spot where rainfall is the major limiting problem associated with revegetation, and irrigation water is scarce.

Discussion:

Snow and rain will both be trapped by water harvesting methods. The results can be 2-3 times more biomass growth from plants exposed to water harvesting than from those that are not exposed to this technique.

What methods of shaping the land result in water harvesting?

Various methods can be used; for example, a water-collection area several feet long can be shaped, or the land can be pitted, contoured, gouged, or chiseled. All of these methods can trap precipitation and direct it into a plant-growing area.

Discussion:

The area to be set aside for collecting water varies, depending on rainfall amount, intensity, and timing, as well as soil infiltration and slope.

For example, if rainfall amounts and intensity are high, a smaller area will be needed as a water-harvesting zone because water runoff will be substantial. In addition, if the infiltration rate of the water-collection site is low, a smaller water-collection area will be needed to get the necessary runoff. These factors will help the vegetation specialist determine the ratio of water-collection area to plant-growing zone. These ratios can range as high as 30:1; on mine sites a typical range is 3:1 to 6:1.

Generally, if the vegetation specialist consistently observes pools of water or gullies originating in the plant-growing zone, the water-collection area may be too large. Preferably, the moisture accumulated will readily absorb into the plant-growing zone.

Which methods work best in mined areas?

Pitting, gouging, or contouring are generally better methods to use on mine sites than is a long water-collection bed. The object in using any of these methods remains the same, however: to increase runoff from the water-collecting zone and increase infiltration in the plant-growing zone.

Discussion:

Usually the slopes on the mine site are so steep that the water collected in long beds will not be distributed evenly onto the plant-growing zone. Long water-collection beds work satisfactorily only on areas where the terrain is flat. Caution should be exercised when considering the use of contour trenches on spoils that tend to settle or spoils that are subject to piping as this might cause slope failures or increased erosion due to water concentration.

Various chemical treatments, including paraffin, silicone emulsion, and polyvinyl acetate, have been used to prevent penetration of water into the water-collection area and thus to increase the amount of water running off into the plant-growing zone. Some of these additives will also aid in stabilizing the water-collection zone's surface. The decision to use a chemical sealing material should be based on the soil characteristics of the site being used as a

water-collection zone. For example, if the soil/spoil is a high sodic, clay type, it tends to seal itself and thus the addition of a chemical sealant does not increase water runoff. In these cases, the cost of using the chemical is not justified.

On the other hand, if the soil is a sandier type, reducing infiltration by using a chemical sealant is important. In these cases, a 25-percent greater plant establishment has been reported on treated areas as compared to nontreated areas.

Mulching will aid in water harvesting because it will improve infiltration and reduce evaporation in the plant-growing zone. Noticeable results have been achieved by using a vertical mulch, which is a method of gouging a narrow slit in the ground near the plants and crimping straw into it to increase infiltration. In addition, both straw and bark have been successfully used as a mulch.

A disk plow can be used to contour the mine slopes; the contour should be broken about every 15 ft. The recommended size of the contours is 1-ft deep and 15-inches wide. A large (5 ton) multi-disk plow may also be used if alternate disks are removed and the largest available blades installed. Contours, under most situations, should not be more than 10 ft apart to prevent accelerated gully erosion.

What are some of the drawbacks of water harvesting?

The expense of shaping a water harvesting site, the unsightliness of large water harvesting areas, difficulties with chemical sealants, the difficulty of getting effective contouring to maximize moisture collection and yet not cause erosion, and the possibility of harvesting salts are all potential drawbacks of water harvesting.

Discussion:

Regarding unsightliness, the principle the vegetation specialist should keep in mind is that even though a parcel of land is being sacrificed to provide more moisture to a smaller plant-growing area, it is expected that once these initial plants are established, plant invasion onto the water-collection site will begin.

Chemical sealants must be monitored to determine whether: (1) they are breaking down too slowly, and thus preventing plant invasion on the water-collection area; or (2) they are breaking down too quickly and thus not allowing enough water harvesting to establish plants in the plant-growing zone.

It is important to tailor the size of the harvesting area to fit the runoff potential of the site. Factors such as slope, infiltration, and rainfall intensity must be considered so that the harvested water will remain in the plant-growing area. If runoff volume from the harvesting slope exceeds retention volume of the plant-growing area, erosion will be accelerated. Careful calculation of the above, taking into account the maximum storm size expected, is critical to success. Contour furrows spaced greater than 10 ft apart, on slopes greater than 15 percent, can accelerate gully erosion. Unbroken contour furrows should not be used.

The first moisture received from a water-collection area in a mine site may contain salts; however, subsequent moisture contains less salt. The salinity of mine spoils would influence the extent of this potential problem; research is being conducted to further study this factor.

COMPANION CROPS

The general term "companion crops" is synonymous with nurse crops or cover crops. A companion crop (also called green mulch) is an annual crop such as peas, barley, or oats that is seeded with perennial species to modify micro-environmental conditions during the initial establishment period. A preparatory crop is seeded before the perennial forage; then the perennial species is seeded directly into the residue left from a preparatory crop without further seedbed preparation. Such crops act as temporary stabilizers of the site while the permanent vegetation establishes.

What are the advantages and disadvantages of companion and preparatory crops?

Although both have potential for use on mined sites, certain climatic regions and topographies are more suited to one than to the other. Decisions on companion crops should be based on site-specific considerations. Table 11 outlines the basic advantages and disadvantages of the two types.

Discussion:

When using companion crops in mineland

Table 11. — *Companion and preparatory crops—their advantages and disadvantages*

Item	Companion crops	Preparatory crops
Advantages	Reduces wind and water erosion Reduces weed competition Protects forage species from wind and severe temperatures Will produce a crop of value prior to development of perennial forage species	Protects topsoil until a permanent species can be established Controls wind and water erosion Reduces evaporation from around seeds and establishing plants Smothers out germinating weeds Reduces or prevents a new crop of weeds
Disadvantages	Can result in severe competition for moisture and light required by the desired perennial forage species	Reduces seed contact with mineral soil if residue is too thick Some cases of phytotoxins left from preparatory-crop residue Can provide competition from volunteer seedlings if preparatory crop permitted to produce seed
Comments	Not recommended for semiarid or arid regions where moisture shortages are likely during establishment period, or on soils of low fertility Especially beneficial in sub-humid and humid regions or with irrigation Where irrigation is available, competition will be lessened; however irrigation also increases changes of success of desired vegetation, even without companion crops. In this care, companion crop has advantage in windy or high temperature sites.	In general, preparatory crops have more application in dry climates of West

reclamation, several considerations should be kept in mind:

• Companion crops to some degree, but especially preparatory crops, will help stabilize the soil/spoil complex after mining by controlling erosion.

• A companion or preparatory crop may provide needed microclimate modifications, which would help establish perennial seedlings; however, as noted earlier, supplemental water is usually necessary to counteract competition for soil moisture in the semi-arid and arid West.

• When choosing species to work together as companion crops, consider combining groups of species, such as fast establishing, short-lived species with slow establishing, long-lived species, or warm-season species with cool-season species.

• When seeding companion crops in a dry climate, use a low seeding rate (for example, 7-10 lb/acre of oats).

• Stubble from a preparatory crop acts as a temporary site stabilizer. When the desired species is seeded into the stubble, there is less moisture competition because the preparatory crop is not alive; however, it provides erosion control and lowers evaporation and surface temperatures.

CULTIVATION

Cultivation is used as a cultural treatment after the establishment of the plant, particularly for shrubs and trees. Cultivation will mix the soil material and provide weed control. It will also break up the surface crust, which will improve

water infiltration, promote soil aeration and increase the root system by maintaining optimum aeration and fertility.

When should cultivation be done?

Cultivation should be done on dry soil and often enough to keep the area fairly free from weeds during vegetation establishment.

Discussion:

Summer fallowing is recommended; if weeds are controlled for 6 months after planting, plant growth will increase substantially.

What techniques are adequate for cultivating?

Implements such as deep moldboard plows, tooth harrows, and roto-tillers may be used.

Discussion:

When using a roto-tiller, it is advisable to remove a few of the prongs so the implement stays at least 6 inches from the shrub or tree.

Another technique is strip cultivation; it is recommended on relatively harsh sites, such as bentonite clay spoils, because it conserves moisture. In this technique, roto-till a strip in an area that has been seeded with grasses and saltbush; plant trees in the strips; and cultivate the strips every spring. Use a chemical emergent treatment within the 6-inch area near the stem of the shrub or tree to prevent weed encroachment.

Chapter 7
MANAGEMENT PLAN AND MONITORING

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Proper management and monitoring of the reclaimed site are vital to maintaining its stability. Considerations of protection needed at the site; methods to evaluate and nurture the vegetation resource; and provisions for special emphasis areas should be included in the management plan. Once this plan has been set, industry personnel and/or the land-management team are responsible for monitoring the site to make sure that the agreed-upon goals are being adequately met.

PROTECTION OF THE RECLAIMED SITE

When should a reclaimed area be protected?

Whenever the vegetation on the site may be threatened by livestock, wildlife, invading weeds, or human traffic, the rehabilitated area should be protected, at least temporarily.

Discussion:

Animal use of rehabilitated sites can be compatible with vegetation establishment and maintenance. Management plans that include use of the site by animals can be successful as long as the management team realizes that reclaimed areas may be more sensitive than adjacent rangeland, and that special standards govern their rehabilitation. For example, seeded areas sometimes will attract animals such as deer in numbers sufficient to damage the stand. Rodents and rabbits can also damage the vegetation. These animals are attracted by the lushness and palatability of the planted vegetation. Thus, if pressure from animal invasion becomes too great, steps should be taken to protect the site.

What techniques are recommended for protecting the site against livestock?

A variety of techniques are successful; however indirect methods of keeping livestock away from a site are less costly than direct methods.

Discussion:

Indirect methods for protecting a site against livestock include:

- Adding less palatable species to the seed mixture;
- Salting away from the seeded area—no closer than one-fourth mile;
- Providing permanent water away from the seeded area; fencing out nearby water;
- Adjusting the use of livestock on the site to allow plants to mature by using a temporary alternative area for grazing, or by requiring nonuse during seedling establishment;
- Moving livestock off the area when allowable use is reached on the revegetated site.

Direct methods include:

- Barriers. Metal or wood devices, varying from the common barbed-wire fence to brush piles (fig. 45), are effective.
- Repellents. Those used to repel wild ungulates have some effectiveness on sheep and cattle (see section on wild animals); however, specific repellents to discourage livestock use have not been fully developed.
- Herding. This requires the use of herders to keep animals contained on areas other than those recently reclaimed.

What techniques are recommended for protecting the site against animal wildlife?

Again, various techniques are successful; the vegetation specialist should employ those that are most effective in preventing overuse of the vegetation as food and habitat.

Discussion:

Indirect methods for protecting a site against wild animals include:

• Using plant species that are undesirable to deer and elk;

• Using plant species that mature about the same time as native species;

• Avoiding hay as mulch where it may attract big game;

• Controlling the deer population through hunting permits, particularly in localized areas during plant establishment.

Direct methods for protecting a site against wild animals include:

• Barriers (fig. 46). Metal, plastic or wood devices, varying from woven wire fence to brush piles, which prevent browsing can be used. Four to six inch diameter plastic tubing placed over trees or plants to be protected have been effective in the Northeast. Woven wire fences 8-ft high are recommended to exclude antelope, deer, and elk. Slash piles over seedlings or plantings discourage browsing while the plants gain height.

• Repellents (fig. 47). The effectiveness of repellents depends on the plant species to be protected and the availability of other vegetation in the area. It has been found that repellents may not be effective when the vegetation is being irrigated. Apparently, the lushness of the vegetation is so attractive to the animals that the repellents do not deter them. Some repellents and the animals they repel are listed in table 12. Specific repellents to discourage rabbits and rodents have not been fully developed.

• Herding. This can be achieved with noisemakers, such as metal cans or acetylene guns. Lights and mirrors have also been used, as have tethered dogs.

• Poisoning. Small mammals can be controlled by poisoning. Check State and Federal regulations on use of poisons.

• Encouraging predator invasion. Roosts, rock piles, etc., will provide a habitat for predators and thus control small mammal populations.

When and how must an area be protected against weeds?

Weeds may have to be removed from a rehabilitated site for a variety of reasons: they present a fire hazard, especially along roads; are esthetically displeasing; are noxious; or provide too much competition with desired plants. Both mechanical and chemical means can be employed. In general, chemical means should be used only in highly selective situations such as for control of noxious weeds.

Discussion:

Mechanical means include:

• Mowing. Weeds must be kept down below 6 inches;

• Shredding. Needed for woody-type weeds;

• Cultivation. Last resort due to wind and water erosion and cost of operation.

Chemical means involve the use of plant regulators, which are any substance or mixture of substances that affect physiological action, growth rate, or other behavior of plants. Plant regulators include:

• Herbicides;

• Defoliants (any substance or mixture of substances used to cause leaves or foliage to drop from plants);

• Desiccants (any substance or mixture of substances used to accelerate the drying of plant tissues artificially).

Table 12. — *Common animal repellents*

Compound	Animals repelled
Tetramethylthiuram disulfide	Rodents and deer
Bone tar oil	Carnivores
9, 10-anthraquinone	Birds
4, aminopyridine	Birds
0, 0-Dimethyl-0-4-methylthio-m-tolyl phosphorothioate	Birds
3-chloro-p-toluidine hydrochloride	Birds

Figure 45. Brush can be used on the site to protect young seedlings during establishment.

Figure 46. Deer-proof fence.

Figure 47. Applying repellent next to deer-proof fence.

Caution: Herbicides can cause injury to humans, domestic animals, desirable plants, fish, and other wildlife. In addition, they should not be used over or directly adjacent to irrigation ditches, ponds, lakes, streams, or homes. Thus, it is important to note that all directions and precautions on the container label be closely followed. Federal, State, and county laws and regulations governing the use of herbicides must also be adhered to. This will be the responsibility of both the land manager and the applicator. Before using any chemical, check to make certain the chemical is registered for the planned purpose.

Additional Information:

Consult with your regional reclamation specialist, local Soil Conservation Service offices, the USDA's Cooperative Extension Service, or pesticide dealers for specific information on the best chemical means for protecting the site from weeds.

When should insecticides be considered?

Before making any attempt to control insects, you should know (1) the name of the insect you want to control; (2) the dangers of using chemicals to control insects; and (3) whether the harm caused by the insects is sufficient to warrant use of an insecticide.

Discussion:

If you do not know the name of an insect, a county agent can help. The vegetation specialist should also realize that some insecticides are highly toxic; it is absolutely necessary to read and follow all warnings on insecticide labels. In addition, Federal and State regulations have established limits on insecticide use. Follow product directions for application to make sure these standards are adhered to.

What kinds of insecticides are recommended?

Sprays and dusts can both be used; sprays have proved as effective as dusts, provided the correct amount of insecticide is applied per acre.

Discussion:

Sprays have certain advantages over dusts: they drift less and can be applied in winds up to 10 mi/hr; less labor is required for handling liquids than dusts; sprays are less apt to be washed off by rain. Also note that nearly all insecticides are known by more than one name. Always check the label to make sure you are buying the correct chemical.

SUCCESSION

Because reclamation efforts ultimately aim at restoring the land to a self-sufficient state, natural succession becomes one of the primary goals of the revegetation process. Thus, during reclamation and postmining, the vegetation specialist should be able to determine whether or not desirable plant succession is taking place.

What methods can be used to study plant succession?

Two direct methods can be used: plant succession studies on the same plot; and plant succession studies done by comparing two different areas.

An indirect method is to relate wildlife preference by the type of wildlife and livestock inhabiting the area to the kind of plant succession that is taking place. Information on the types of herbage preferred by various animals is available from wildlife specialists.

Discussion:

Plots on the same area:

- Permanent plots are established, labeled, and measured at intervals over several years. Criteria measured can include: plant frequency, diameter, height, canopy cover, denisty, mortality, and biomass of the plants. Measurements can be done manually, by photographs, or through historical and file records, including vegetation maps. Manual studies are the most accurate way to measure succession; they also require more labor.

In comparison studies, two approaches can be taken:

- Measure two different sets of plots, each in a different locality, but with the same ecological conditions, and compare succession trends.
- Infer from records on other studies of disturbed sites what kind of succession is taking place on the rehabilitated site; dates of disturbances must be known to make a useful comparison.

PRODUCTIVITY

Measures of plant productivity are also important in analyzing the success of the reclamation program.

What productivity measurements can be used?
Frequency of plant occurrence, changes in morphological characteristics, and volume measurements can all be used (fig. 48-50).

Discussion:

Frequency of occurrence:

- Canopy cover of a plant species on study plots can be measured.
- Certain plants within study plots can be counted and compared either over time or with another study plot (example: number of shrubs per acre).

Changes in morphological characteristics:

- Identify the morphological characteristic that best applies to the species being measured.
- For grass species, morphological characteristics can include the number of leaves, length of leaves, length of flowering columns, length of spikes, and number of flowering columns per clump or per area.
- For trees, current annual growth can be determined by measuring twig length or by harvesting the twig and determining length to weight relationship.
- For shrubs, measure twig length, length to weight relationship, leaf length, or leaf width.

Volume measurements:

- A simple volume estimate can be obtained by measuring the length, width, and height of small trees or shrubs on the site, especially plants that produce a large amount of side branching.
- A more accurate volume measurement is to relate volume, as measured by length, height, and width, to the weight of the shrub. This is done by harvesting, measuring, and weighing approximately 20 plants of the same species. Based on these figures, the weight of other shrubs can be estimated from volume measurements taken in the field.

Figures 48-50. Measures of plant productivity are used to analyze the success of the reclamation program. From top to bottom: measuring twig length, leaf length, and plant height.

How is plant harvesting done?
If harvesting is used, choose a random site or representative area on the site and harvest by

clipping all species at ground level within frames or by harvesting current annual growth.

Discussion:

If harvesting is used, choose a study area, place a circular loop on the area, and harvest within the loop. Or, estimate the weight of the plants within the circle, but harvest the species outside the plot (double-sampling procedure). The plants harvested can then be accurately measured and that figure can be applied back to the estimated values.

Perhaps the most commonly used method is simply to go to the revegetated site and harvest the plants for which you want production figures.

It is important to select harvest dates that correspond to collection of baseline data so that valid comparisons and evaluations can be made.

Certain measurements do not require harvesting, such as on-site measurements of morphological characteristics. Careful recordkeeping is essential.

UTILIZATION

With rare exceptions, a goal of reclamation is to put the land back into a form in which it can be utilized by livestock or wildlife. Thus, measuring utilization becomes another management task during the postmining phase.

How is utilization measured?

Techniques used to measure utilization include: (1) comparison of a grazed area with an ungrazed area and measuring the difference in plant standing crop, morphological characteristics, and shrub length, width, and height; (2) measurement of water intake by livestock, taking into account evaporation losses, the amount of moisture in the herbage and air temperature (this figure, coupled with dietary analysis, will enable the land manager to calculate utilization); or (3) review of the dietary preference list of wild animals in the area.

Discussion:

When comparing grazed to ungrazed areas:

- A portable cage can be placed over an area to be measured, and this can be moved throughout the grazing season after each harvest. When the cage is moved, harvest the herbage under the cage and harvest adjacent to the cage, then calculate the difference. This difference indicates utilization.

- A permanent exclosure may also be used; however, it is a less satisfactory indicator of utilization because the parameters inside an ungrazed permanent exclosure are much different from the areas that have been grazed.

REFERTILIZATION

As noted in the discussion of fertilization in chapter 6, mine spoils in the West are commonly deficient in nitrogen and phosphorous. Thus, during the postmining monitoring period, it is quite likely that a refertilization program will have to be established to ensure that the site receives sufficient nutrients to permanently establish vegetation.

How are refertilization needs identified?

Several methods can be used to determine refertilization needs: soil tests, tissue tests, observing deficiency symptoms, greenhouse testing, and field plots.

Discussion:

Soil tests are an important method for identifying nutrient deficiencies, with the exception of nitrogen, which is best detected by on-site observations or field plot studies. Tissue tests and greenhouse tests can supplement these methods. When using soil analysis, rely on qualified suggestions of State testing labs or commercial labs; follow recommended procedures for soil sampling. More information on observing deficiency symptoms can be found in chapter 6.

How should the soil sample be taken?

Most experts outline the following suggestions:

1. Each sample should represent no more than 10 acres.

2. Ten to twenty samples are recommended depending on site variability.

3. Rooting depths of vegetation will guide how deeply one should sample.

4. Samples every 2-4 years are recommended.

5. Sample when moisture conditions permit; a given area should be sampled about the same month each year to allow for nutrient variability during the year.

6. Sample at a time so that fertilizer, if needed, can be applied before the next growing season—this means fall or early spring sampling.

What amounts of nutrients are required?

This, of course, depends on the efficiency of the fertilizer, nutrient status of the spoil, and the deficiency in the plants.

Discussion:

Various guidebooks are available that will aid in this determination. Results of soil tests and field plots will also indicate the extent of refertilization required. The land manager should also be aware of the history of fertilization on the area, because rates of refertilization will depend on what has been done in the past. (For more specific information, refer to chapter 6.)

Additional Information:

For chemical analysis procedures, refer to "Laboratory Methods Recommended for Chemical Analysis of Mined Land Spoils and Overburden in the Western United States," by F. M. Sandoval and J. F. Power. USDA Handbook 525. 1977.

SPECIAL EMPHASIS AREAS

Some areas will need special attention during reclamation and postmining. These areas include closed roads, harsh sites, and those sites where rehabilitation failed.

How is road reclamation achieved?

For the most part, road beds can be successfully revegetated using ripping, surface treatments, and hydromulch seeding techniques. In some cases, however, successful maintenance may mean road closure. The goal of road reclamation is to control any erosion, siltation, or water pollution caused by roads.

Discussion:

Asphalt mixed with mulch and seed has been successful in binding the mulch and seed to the road bed. Consult State highway departments for seeding formulas and other recommendations.

What types of harsh sites will require special attention?

Harsh sites that require special attention to achieve reclamation include southerly exposures in arid areas; subalpine, highly saline, or alkaline lands; and coarse-textured materials (fig. 51).

What is meant by special emphasis on reclamation failures?

Failures may result because of weather, rodents, insects, diseases, or bad management. This failed area must be given special attention during postmining and then must be monitored more carefully than successful sites.

Discussion:

It is important to note that some stands may take from 2-5 years to become established in arid and semi-arid areas. Often, plantings that were thought to be a failure at the end of the seeding year may develop into excellent stands because seeds may germinate 1 or 2 years after seeding if moisture was not available earlier. Thus, plantings should not be destroyed until they have been thoroughly examined.

MONITORING

Although the Surface Mining Control and Reclamation Act of 1977 (P.L. 95-87) applies only to coal, a statement relating to monitoring in Section 515.19 has general applicability when it states that the reclamation manager must "establish on the regraded areas and all other lands affected, a diverse, effective and permanent vegetative cover of the same seasonal variety native to the area of land to be affected and capable of self-regeneration and plant succession at least equal in extent of cover to the natural vegetation of the area; except that introduced species may be used in the revegetation process where desirable and necessary to achieve the postmining land use plan."

This effort must then be maintained for a required number of years after initial reclamation work is completed. Although another land use, such as for agriculture, or various State laws, may not make the above statement totally

Figure 51. Harsh sites, such as these bentonite spoils ponds, will require special reclamation emphasis and monitoring.

applicable, it does serve to emphasize that monitoring the reclaimed land will be an important function.

What is the role of the vegetation specialist in respect to monitoring?

The vegetation specialist should systematically monitor the revegetated mine site. Based on his input, the land manager will determine if the goals stated in the mining plan are being met.

Discussion:

Specifically, the vegetation specialist should consider the following:

- He should know what was stipulated in the mining plan; what are the agreed-upon goals of the reclamation effort. For example, in the mining plan the operator and land manager will have agreed when rehabilitation will be considered complete—when the land is revegetated, or when the land is being used by livestock or wildlife again.
- He should oversee augmented seeding, refertilization, irrigation, and any other work necessary to insure the establishment of permanent plant cover.
- He should set up a program to measure succession, productivity, and utilization on the site.
- Fundamental principles of rest-rotation grazing, deferred grazing, and grazing after seed maturity should be followed.
- Accurate recordkeeping of all these activities is necessary, especially if a question arises when the mining operator's bond of liability is to be released.
- The operator should be informed of the techniques the vegetation specialist will use to monitor the reclaimed site.
- If necessary, the vegetation specialist can recommend revisions in the postmining plan.

How long must the site be monitored?

Experience in end-use monitoring in the West is not sufficient at this time to state a number of years; however, some laws are setting such guidelines.

Discussion:

As one example, in the case of coal mined in areas with less than 26 inches of annual precipi-

tation, the Surface Mining Control and Reclamation Act of 1977 states that, with certain exceptions, the mining operator is responsible and liable for the success of the reclamation effort for a period of 10 years after the last year of augmented seeding, fertilization, irrigation, or other work. Here, the vegetation specialist's role as a monitor would extend at least that many years. In other cases, the time that elapses before the operator is totally released from his bond will depend on the stipulations of the mining plan. Even after the operator is released from his bond, however, the vegetation should be monitored by the land-management agency.

What are the main areas that are considered critical in postmining monitoring?

The possible pollution of surface and subsurface water and erosion are two of the major areas that must be closely monitored. Federal, State, and local laws, however, may affect the
State, and local laws, however, may affect the

Discussion:

If a State requires succession of native species, the vegetation specialist will have to give special attention to determining if native species succession is occurring.

Additional Information:

Recommended texts on several of the subjects covered in this chapter include:

"Techniques for Vegetation Measurements and Analysis for a Pre and Post Mining Inventory," by C. Wayne Cook and Charles D. Bonham, Colorado State University, Range Science Dep., Science Series 28. August 1977.

"Methods for the Measurement of the Primary Production of Grassland," by C. Milner and R. Elfyn Hughes, International Biological Programme (IBP) Handbook No. 6. 1968.

"Range Research Methods," a symposium sponsored by the Division of Range and Wildlife Habitat Research, USDA For. Serv., May 1962. Miscellaneous Publication No. 940, U.S. Dep. of Agric.

"A Prediction Model to Estimate Revegetation Potentials of Land Surface Mined for Coal in the West," by Paul E. Packer, Chester E. Jensen, Edward L. Noble, and John A. Marshall. Proceedings of the International Congress on Energy and the Ecosystem, University of North Dakota, Grand Forks, N.D. June 1978.

APPENDIX A

GLOSSARY

Acidic soil: A soil that contains a preponderance of hydrogen ions, often occurring when sulfide minerals are oxidized. Values below pH 7 indicate an acidic soil.

Adapted species: Species that can complete their entire life cycles and replace themselves in succeeding generations. Both introduced and native species can be adapted species.

Alkaline soil: Soil with a pH above 7 and which contains excessive concentrations of soluble "salts"—ions of calcium, magnesium, potassium, sulfate, chloride, nitrate, boron, and others. (Also see: sodic soil.)

Bare-root stock: Nursery stock grown 1-2 years in beds, after which the individual plants are dug up while dormant and are replanted.

Baseline data: Data gathered prior to mining for the purpose of outlining conditions existing on the undisturbed site. Reclamation success is measured against baseline data.

Broadcast seeding: Randomly scattering seed on the ground's surface. Aerial seeding and hydroseeding are types of broadcast seeding.

Companion crop (synonymous with **nurse crop or cover crop**): An annual crop, such as peas, barley, or oats, that is seeded with perennial species to modify microenvironmental conditions during initial establishment.

Container-grown planting stock: Stock cultivated in small containers and planted as seedlings.

Critical area: An area that should not be disturbed (i.e., mined) because it is deemed extremely difficult or impossible to reclaim.

Cuttings: Sections of stems or branches, usually from woody plants, that are either cut from a plant and replanted at the site being revegetated, or cut from the plant, rooted in a nursery, and planted as a transplant.

Drilling: A method of planting in which seeds are dropped into holes or furrows and covered with earth.

Electrical conductivity (EC): Electrical conductivity of a saturated extract used to measure soluble salts. A soil is considered saline if the EC of a saturated extract is 4 mmho/cm (U.S. Salinity Lab Staff).

Environmental Assessment (EA) (replaced the **EAR**): An analysis of all actions and their predictable short- and long-term environmental effects, which include physical, biological, economic, and social factors and their interactions. Also, a concise public document required by the regulations for implementing the procedural requirements of the National Environmental Policy Act of 1969 (NEPA).

Environmental Impact Statement (EIS): A document prepared by a Federal agency in which anticipated environmental effects of a planned course of action or development are evaluated, as described by the National Environmental Policy Act of 1969 (NEPA).

Exchangeable sodium percentage (ESP): The percentage of exchangeable sodium ions to other exchangeable cations in the soil. If this figure is 10 percent or higher, the soil may be sodic.

Feasibility study: As applied to mining, the feasibility study follows discovery of the mineral and is done by the mining company. Its purpose is to analyze the rate of return that can be expected from the mine at a certain rate of production. Based on this study, the decision to develop the ore body may be made.

Frost heaving: A condition that results from the flow of water through the soil to a freezing front where layers of ice are formed. This condition can thrust germinating seedlings out of the soil.

Hardening: Toughening of plants, especially container-grown stock, prior to planting by exposing the seedlings to colder temperatures and less

moisture. This enables the plants to make the transition from the controlled environment of a greenhouse to the harsher conditions of the mined site.

Hydromulching: Spraying mulch on the site with a stream of water.

Hydroseeding: Spraying seed on the site with a stream of water.

Inoculation: Treating seeds with appropriate host organisms, such as N-fixing bacteria, prior to planting.

Interdisciplinary team (ID team): As proposed by recent Forest Service regulations, the interdisciplinary team will be comprised of Forest Service personnel who collectively represent two or more areas of specialized technical knowledge about natural resources management applicable to the area being planned. The team will consider problems collectively, rather than separate concerns along disciplinary lines. This interaction will insure systematic, integrated considerations of physical, biological, economic, and other sciences.

Introduced species: A species that may be adapted to an area, but not native to it. An example would be alfalfa grown in the West.

Land-management plan: According to Forest Service regulations, each forest must have a forest plan, which outlines the most desired and alternative land uses for that site.

Mining plan: Submitted by the mining operator, the mining plan outlines the steps the mining company will take to mine and rehabilitate the site. The mining plan is submitted prior to start-up of mining operations.

Monitoring: In regard to disturbances caused by mining, the site must be carefully observed following reclamation operations to insure that reclamation goals are being met. This monitoring usually involves observations over time.

Mulch: Any nonliving material placed or left on or near the soil surface for the purpose of protecting it from erosion or protecting plants from heat, cold, or drought.

Native species: Plants that originated in the area in which they are found; i.e., they naturally occur in that area.

Nurse crop: See companion crop.

Overburden: Material overlying a minable deposit up to, but not including, the topsoil.

Oxidation of soil: The combination of substances in the soil with oxygen. If the substance is a sulfide, this oxidation may result in an acidic condition.

pH: Symbol for the negative common logarithm of the hydrogen-ion concentration (acidity) of a solution. The pH scale runs from 0 to 14. A pH of about 7 is considered neutral. A pH number below 7 is acidic and a pH value above 7 is alkaline or basic.

Plugs: Field-grown, native clumps of vegetation, dug up and replanted in another site. Plugs may contain several plant species.

Preparatory crops: A crop seeded before perennial species; then the perennial species is seeded directly into the residue left from a preparatory crop without further seedbed preparation.

Primary species: Generally the first species to naturally invade a disturbed site. Primary species will colonize and initiate plant succession on the site.

Productivity: In reference to vegetation, productivity is the measure of live and dead accumulated plant materials. It is used to assess revegetation success.

Reclamation: Returning disturbed land to a form and productivity that will be ecologically balanced and in conformity with a predetermined land-management plan.

Rehabilitation: See reclamation.

Rhizomes: Underground stems of grasses, sedges, and other plants.

Saline soil: Soil containing sufficient salts to interfere with the growth of most crop plants.

A saline soil is indicated when the EC of a saturated extract is greater than 4 mmho/cm.

Sodic soil: A sodic soil occurs when exchangeable sodium ions are so concentrated in the soil that they may adversely affect plant growth. An ESP of 10 percent or higher, or an SAR of 10 or more, may indicate a sodic soil.

Sodium adsorption ratio (SAR): A lab measurement of the ratio of soluble sodium to soluble calcium plus magnesium in soils. If the SAR is 10 or more, the soil may be sodic.

Soil: The loose, uncemented minerals and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants; in this definition, soil only extends to the depth important for plant growth.

Spoils: The overburden (soil and raw geologic materials) removed in gaining access to the desired mineral deposit.

Sprigs: Pieces of grasses and sedges that can be rooted and replanted.

Succession: The process whereby one association of species replaces another, or the progressive changes in vegetation over time on an area.

Toxic soil: A soil containing concentrations of minerals so high as to be harmful to plants or animals.

Topsoil: The original or present dark-colored upper soil that ranges from a mere fraction of an inch to 2 or 3 feet thick on different kinds of soil. Most organic matter is concentrated in the topsoil.

Utilization: In reference to vegetation, utilization measures the amount of vegetation being used by animal species for forage in relation to the total amount of vegetation or given animal species available for grazing use.

Water harvesting: The practice of using the landscape to collect and accumulate water runoff and concentrate that moisture in a plant-growing zone.

Wildings: Individual plants transplanted from the wild to another site.

APPENDIX B

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APPENDIX C

INDEX

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USDA Forest Service.
1979. User guide to vegetation. USDA For. Serv. Gen. Tech. Rep. INT-64, 85 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Summarizes and discusses key questions and rules the vegetation specialist should consider when working in mining area reclamation. Topics include land-management planning and baseline data; species selection; plant materials; site preparation; planting methods; cultural treatments; and postmining monitoring.

KEYWORDS: vegetation, revegetation, mining, mining area reclamation, mining area rehabilitation, land-management planning process.

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THE SEAM PROGRAM

The Surface Environment and Mining Program, known as SEAM, was established by the Forest Service to research, develop, and apply new technology to help maintain a quality environment while helping meet the Nation's mineral requirements. SEAM is a partnership of researchers, land managers, mining industries, universities, and political jurisdictions at all levels.

Although the SEAM Program was assigned to the Intermountain Station, some of its research projects were administered by the Rocky Mountain and Pacific Southwest Research Stations.

MINERAL USER GUIDES

Other User Guides for specialists involved in minerals activities are:

- User Guide to Soils, Gen. Tech. Rep., INT-68
- User Guide to Engineering, Gen. Tech. Rep., INT-70
- User Guide to Sociology and Economics, Gen. Tech. Rep., INT-73
- User Guide to Hydrology, Gen. Tech. Rep., INT-74
- User Guide for Wildlife (planned)
- User Guide for Visual Management (to be published as part of the National Forest Landscape Management Series)

To obtain copies of these guides, write: Intermountain Forest and Range Experiment Station, USDA Forest Service, 507 25th St., Ogden, UT 84401.

NATIONAL FOREST SYSTEM COOPERATIVE FORESTRY FORESTRY RESEARCH
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